MODERN FISHING GEAR OF THE WORLD: 3

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Editor:
HILMAR KRISTJONSSON

Fish Finding
Purse Seining
Aimed Trawling

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NOTICE TO THE READER

THIS volume contains the edited papers and discussions thereon at the third Congress on Fishing Gear organized by the Department of Fisheries FAO and held at Reykjavik in August 1970.

As explained in the preface, special attention was devoted to the three principal subjects covered, it being felt that the two preceding Congresses had provided an adequate basis of knowledge on the general subjects of modern fishing gear. In that sense this work is a specialized treatment of these subjects—Fish Finding, Purse Seining and Aimed Trawling—on which the greatest advance has been made in recent years. The List of Contents gives the subject matter covered in the various sections so fully that a detailed index is felt to be unnecessary.

The major preliminary organizing and editing of the Congress and the book was undertaken by Hilmar Kristjonsson (who edited the two preceding volumes) but in the latter and final stages detailed supervision was given by Dr. J. Schärfe, chief, Fishing Gear and Methods Branch of the Fishing Industries Division, in succession to Hilmar Kristjonsson.

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PREFACE

THE FAO Technical Conference on Fish Finding, Purse Seining and Aimed Trawling held at the kind invitation of the Icelandic Government in Reykjavik in May 1970, was the third of the international conferences on fishing methods and gear sponsored by the Food and Agriculture Organization of the United Nations. The preceding Fishing Gear Congresses, 1957 in Hamburg and 1963 in London, which have helped to establish fishing technology as a discipline, attempted to cover the whole field of fishing gear and fishing operations. This was then essential because the literature on the subject was incomplete and scattered and international communication and cooperation in this newly developing field was in its infancy. Since then the FAO fishing gear meetings have become the established forum for the exchange of views and results and attract the leading experts from the fishing and fishing supply industry and from related research and development institutions all over the world.

Because the proceedings of the first two FAO Fishing Gear Congresses published in *Modern Fishing Gear of the World* Volumes I and II, provide a good general basis, the scope of the third meeting was confined to the three selected subjects considered to be of major significance for fishing development and in which particularly noteworthy progress had been achieved in recent years.

Fish finding is a prerequisite of all rational fishing efforts and one of the determinants of economic efficiency. Even in highly developed trawling about 50 per cent and in purse seining about 80 per cent of the time available for fishing has to be spent on searching for fish. Progress in the instrumentation and techniques of fish location and fish detection is therefore bound to have significant effects. This applies particularly to developing small boat fisheries where the introduction of even simple echo sounders, not to mention sonar techniques, will inevitably have a decisive impact on increased catches, improvements in gear, boats and methods and thus on the direction and speed of progress as a whole. A specific line of development aims at applying echo sounding in quantitative exploration and assessment of fish stocks and it is certain that commercial fishing will benefit from the instrumentation and techniques developed for and the experiences gained in this work. Netsonde sounding in combination with ship's sounder and sonar, as well as sophisticated electronic sector scanning sonar techniques, are becoming more and more powerful tools for the observation of fish and their reactions to fishing vessels and fishing gear. This obviously opens up greatly improved means for the more rational control of fishing operations and further development of fishing gear and techniques. The utilization of long range observation of environmental factors, such as water surface temperatures, boundaries of water bodies, currents and areas of upwelling by aircraft and satellites for the determination of likely fishing areas and their movements in time and space is developing. With adequate international cooperation, this may lead, in the not too distant future, to the establishment of fishery situation and forecast systems for strategy planning and for the identification of areas with greater or so far unknown fishing potentials.

With the growing impact of fish finding sonar and the subsequent development of larger nets, more powerful hauling machinery, larger vessels and the introduction of vessel operational aids, such as thrusters or active rudders, **purse seining** has taken a further step towards improving its already high efficiency. This technological development, which has been particularly noteworthy in Scandinavia, Iceland and in the U.S.A. tuna fishery, is naturally promoting similar progress in other fisheries. The "sonar guided" purse seining technique, through which the fishing range and depth could be increased considerably, may involve the risk of creating new conservation problems. On the other hand, it has already enabled the exploitation of so far under-exploited or neglected fish stocks and will continue to contribute significantly to the better utilization of marine resources. Developing

fisheries will first benefit from the progress in materials, gear construction, vessel layout and mechanical aids but the more sophisticated operational tactics will doubtless also find gradual application and prove their value.

Aimed trawling signifies the milestone in this second important fishing technique between blind groping by trial and error and instrument controlled, rationally directed catching operations. This concept, which involves all measures for the efficient "aimed" juncture of trawl and fish, originated from the development of one-boat midwater trawling, which has meanwhile been firmly established in commercial trawling. It is now being extended also to bottom and semi-pelagic trawling and in its new definition embraces all relevant aspects with regard to fish and environment, from material, gear construction, fish finding and observation, and vessel and gear control to operational techniques and tactics. Of all fishing techniques, trawling has so far received the most intensive attention from research efforts and recent progress in instrumented observation and measuring systems on board and on the gear has consequently been impressive. Examples are the spreading use of gear telemetry and computerized data logging and evaluation. The results and experiences gained with such sophisticated techniques on trawl dynamics and the interrelation between vessel, trawl gear and fish reactions, together with numerous less spectacular technical advances, such as: new materials for yarns, ropes and floats; large mesh size and hydrofoil otter boards for reduced towing resistance; better and cheaper echo sounders for fish detection; simplified netsonde equipment for better gear control, and improved trawling techniques in general, are naturally not restricted to large units and highly industrialized fisheries. After due evaluation and appropriate selection they will inevitably promote progress in trawling on all levels.

Under these three main headings 88 papers were submitted and discussed at the Conference by more than 300 participants from 35 countries. The papers and discussions, which comprise this book, may not be completely comprehensive but they certainly give a fully adequate account of the subject matter and also, in the last chapter, a highly educated view into the future of fisheries in general. It may therefore be anticipated that it will find as high appreciation as did the preceding two volumes.

When going through this third gear book and comparing it with the previous volumes, one cannot help but be impressed by the increasing attention paid to, and the resulting accelerated speed of progress in rational fishing gear and methods research and development. Another noteworthy trend is the growing awareness of the need for international cooperation and coordination in this field—the need to join forces for mutual benefit and to avoid wasteful duplication of efforts.

The demands for appropriate training to enable fishing skippers and other operators to utilize the more and more sophisticated (and expensive) instruments and techniques to full advantage is growing accordingly and modern training aids like wheelhouse mock-ups and computerized simulators are being developed. Fisheries of a high technical level will soon require a new and different type of skipper and officer with a college or technical university background and this trend has already started in some countries.

This requirement contributes to increasing the importance of the human factor in fishing where, in competition with shore based employment opportunities, some fisheries have found increasing difficulties in attracting sufficient suitable applicants for manning their vessels. Strong measures, such as significant improvements in working, living and safety conditions on board; shortening of sea time through exchange or rotation of crews, and better earnings through reduction of manpower by mechanization will be required to solve this problem. This in turn will obviously have a great influence on the size and layout of vessels, design and power of auxiliaries, degree of mechanization and automation of deck operations, engine room, processing and storage facilities, and on operational planning of fisheries in general.

There was some concern expressed in the discussions as to whether a technical fishing gear conference of this level does sufficiently take into account the problems and interests of developing fisheries, the promotion of which is considered to be the main responsibility of FAO. Technical progress in any field, including fisheries, has to rely on progress at higher levels achieved elsewhere. The sponsoring by FAO of international meetings like the Technical Conference on Fish Finding, Purse Seining and Aimed Trawling is, therefore, a significant phase in promoting such development. By bringing the top experts in these fields together and by compiling in this book their critically discussed views and findings, a worldwide review is being made publicly available of the present state and the future trends in this important sector of fisheries. This wealth of detailed technical

information will undoubtedly serve, for some time to come, as a solid base for the future phases of technological progress and it is sincerely hoped that those engaged in commercial fisheries and related research at all levels will find it useful and utilize it to their best advantage.

Thanks are due to the authors of the papers, the speakers who contributed to the discussions and the Secretariat of FAO who combined their efforts to conduct the Conference and to compile this book. I would also like to express FAO's appreciation for the generous hospitality and efficiency of the Icelandic Government in providing its good services and excellent facilities in Reykjavik and in particular to the Minister of Fisheries, Mr. E. G. Thorsteinsson, and his staff and to Mr. David Olafsson, former longtime Director of Fisheries of Iceland who, as General Chairman of the Conference, greatly contributed to its success.

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PART I

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The Icelandic Herring Search and Information Services

by Jakob Jakobsson

Les services de detection du hareng et d'information en islande

Les services de détection et d'information islandais, qui ont recours à la reconnaissance aérienne, sont entrés en existence à la fin des années 20 et sont devenus un service régulier en 1939. Outre la reconnaissance aérienne, des stations radio basées à terre ont été établies au début des années 40, et on a commencé à effectuer des enquêtes soniques périodiques à partie de 1954. Le sonar est utilisé lors d'enquêtes préalables à la campagne de pêche, dont le principal objet est de prendre contact avec des bancs migratoires de harengs à la recherche de nourriture, et lors d'enquêtes menées pendant la campagne dans le but de diriger la flotte vers les concentrations de harengs qui se prêtent aux opérations de pêche. Toutes ces enquêtes ont fait une place importante aux études de milieu. Les réactions du hareng en présence d'un facteur écologique ont servi à mettre au point une technique rationnelle de détection. Les enquêtes soniques ont été particulièrement utiles à la pêche islandaise du hareng. L'un de leurs principaux résultats a été la prolongation de la campagne de pêche, autrefois de deux à trois mois, qui maintenant se poursuit sans discontinuer pendant six à sept mois au large des côtes nord et est. Cette évolution s'est produite au début des années 60. Le document esquisse l'avenir de l'organisation consacrée à la détection du hareng et les développements qui pourraient se produire dans ce domaine lors des prochaines années.

Los servicios islandeses de información sobre la situación de los bancos de arenque

La localización de los bancos de arenque con aviones y la información a los pescadores sobre su situación comenzó en Islandia a finales de los años veinte y se convirtió en un servicio regular a partir de 1939. A los reconocimientos aéreos se sumaron, a principios de los años cuarenta estaciones costeras de radio, y en 1954 se iniciaron sondeos regulares con sonar. Con el sonar se practican reconocimientos antes de que comience la campaña de pesca, para determinar los movimientos migratorios de los arenques en busca de alimentos y durante ella para dirigir a la flota pesquera hacia las concentraciones pescables. En todos los reconocimientos se ha prestado gran atención a los estudios del medio. Las reacciones de los arenques a determinados factores ambientales han servido para preparar una técnica racional de localización. Los sondeos con sonar han sido muy valiosos para la pesquería islandesa de arenque. Un resultado importante ha sido la prolongación de la campaña de pesca en las costas septentrionales y orientales a seis o siete meses, contra los dos o tres que duraba antes. Este cambio se produjo entre principios y mediados de los años sesenta. Se describe brevemente el futuro de los servicios de localización de arenques y los posibles progresos en este campo de investigación en los próximos años.

THE Icelandic herring fisheries have been subjected to large fluctuations in catch rates in the past. Following a period of low yields from the mid 1940's to the late 1950's, yields were very high in the early and mid 1960's (fig 1). The increase in catch was due to a combination of several factors one of which undoubtedly was the success of the Icelandic herring search and information services (Jakobsson, 1959 and 1964; Jakobsson *et al.*, 1968).

The underlying principle is that of increased efficiency with specialization, i.e. the important task of fish location is mainly conducted by a few but specialized ships and personnel by which the fishing fleet is mostly relieved from this task and can spend more time on actual fishing.

The Icelandic herring fishery is based on both Icelandic and Norwegian herring stocks which all have long distance feeding over wintering and spawning migrations. During the summer months great variations in the feeding migrations have been observed in the vast oceanic and coastal areas between Iceland, Jan Mayen, Spitzbergen and Norway. The problem of location thus became even more important and the search and intel-

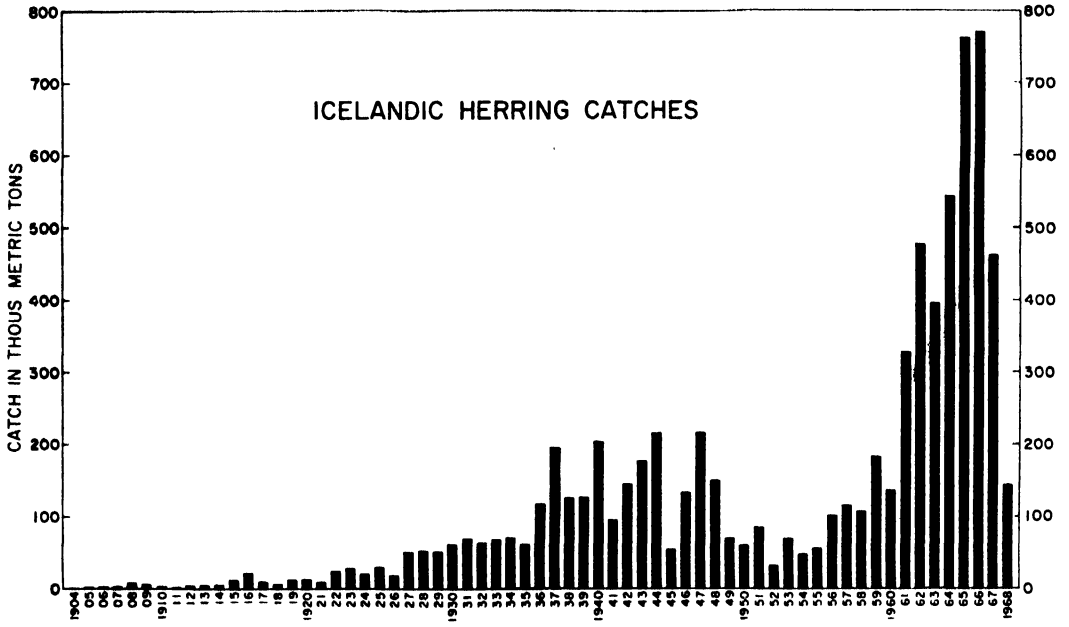

Fig 1. The Icelandic herring catch 1904 to 1968 in 1000 tons

ligence services were further developed and extended to meet the new requirements of the summer herring fishery which traditionally took place off the north coast of Iceland and for many years was the most important herring fishery in Iceland.

DEVELOPMENT OF HERRING SEARCH SERVICE

Until the introduction of acoustic ranging in 1953 organized herring searching in the north coast fishery depended almost entirely on visual sighting of surfacing schools. The aerial scouting for herring which started in 1928 was closely linked with the early stages of aviation in Iceland. The aerial scouting service was pioneered by Dr. Alexander Jóhannesson, a great flying enthusiast at the University of Iceland (Jóhannesson, 1933). All the leading pilots in Iceland had a hand in herring scouting during those pioneering years.

This service was, however, much handicapped in its early stages by difficulties in communication. Although the scouting airplane was equipped with a radio transmitter, very few herring boats had radio communication. Therefore the information obtained by the aircraft often was a few days old when it reached the fishermen and its usefulness had diminished. But the effectiveness of aerial scouting had been proven so that when radio telephones had been installed in all the herring boats, regular airborne herring scouting was revived as a joint venture by the state owned herring reduction plants and the Herring Board. They used two planes for larger simultaneous coverage of the fishing grounds during the short daily periods of surfacing of the herring schools (Jakobsson, 1959). Aerial scouting was thus well established in the north Icelandic herring fishery from 1939 to 1965. Then it had to be abandoned due to radical changes in schooling behaviour and distribution patterns of the herring. Its importance had decreased considerably soon after 1960.

Throughout the period of aerial scouting the steering committee was lead by Mr. Sveinn Benediktsson, chairman of the State owned herring reduction plants. Much of the success of aerial scouting, especially in the early years, must be credited to his unrelenting enthusiasm and foresight. Although some difference of opinion as to the usefulness of aerial scouting was expressed by the Icelandic herring captains in the early years of the service, the majority of herring fishermen welcomed this new method of location and in 1939 aerial scouting led to large improvement in the herring catches (Benediktsson, 1940).

During the first few years after aerial scouting had been revived the information on sighting went through the usual shore stations but shortly thereafter a special herring information radio station was operated at Siglufjördur (north coast) and later two additional stations were operated at Raufarhöfn (north east coast) and Seydisfjördur-Dalatangi (east coast). These stations were manned day and night and their purpose was to direct the scouting aircraft, rebroadcast all available information from the organized search systems to the fleet, and supply up-to-date information on landing facilities in the many different ports. This last task was often very important especially during periods of prolonged heavy fishing when it became difficult for the captains to decide where they would get the quickest unloading of the catch in relation to the distance from the fishing grounds.

In later years these special intelligence radio stations have also gathered valuable fisheries statistics because every captain has, since 1960, reported the size of his catch and its location as soon as he had finished brailing. Thus all outgoing fishing vessels have had the most up-to-date information as to the best fishing areas and have been able to supplement those with information from the organized search systems as soon as they left port.

Active search and intelligence service had thus become an integral part of the Icelandic north coast fishery several years before the introduction of horizontal ranging in the early 1950's. The first experiments using sonar for locating herring schools in Icelandic waters were carried out by the Norwegian scientist Finn Devold (1950a). His success aroused immediate interest in Iceland and in 1953 sonar was installed in the Icelandic vessel *Aegir* and since then ranging has played a large part in locating herring concentrations. From 1953 to 1958 the main value of such surveys was to locate *probable* fishing areas. Actual fishing did not generally start until the schools surfaced. Information on submerged schools during this period was also valuable for subsequent aerial scouting.

After the development (1954 to 1960) of the Icelandic purse seine shooting tactic where herring skippers use their own sonars for setting the purse seines around submerged schools (Jakobsson, 1964), the value of the organized sonar surveys greatly increased, since concentrations of good schools whether surfacing or submerged down to a depth of 40 to 50 fm could be fished and the hazardous waiting for surfacing of the schools became unnecessary. These sonar surveys became especially valuable during 1961 to 1968 when distribution of herring concentrations gradually became more and more oceanic and surfacing of schools less frequent with resulting inefficiency of aerial scouting. During 1954 to 1955 only one research ship, the *Aegir*, was engaged in systematic sonar survey work but from 1956 to 1961 an additional scouting vessel was used to support the research vessel and during 1961 to 1967 three ships have been used, i.e. one research ship equipped with a laboratory and facilities to carry out hydrographical and biological (plankton) surveys, and two scouting vessels commanded by experienced fishing captains. All three ships were equipped with the best available long range sonar. In 1968 and 1969 the sonar survey work has mainly been carried out on the *Arni Fridriksson*, the new herring research vessel constructed in 1967. In addition there have been one or two support scouting vessels in the last three years.

ORGANIZATION OF SONAR SURVEYS

Since the so-called Icelandic "north and east coast" summer fishery is based on the feeding migrations of

Icelandic and Norwegian herring stocks it is obviously the main task of the herring search services to locate and trace the movements of these stocks. In order to facilitate a better understanding of these migrational patterns much emphasis has been placed on environmental investigations. Thus extensive hydrographical as well as phyto and zooplankton investigations have been carried out annually in May and June, usually in cooperation with Norwegian, Soviet Union and, in earlier years, Danish research vessels. During these pre-seasonal cruises, the first phase of the herring migrations were charted in relation to hydrographic and biological features of the areas investigated. Based on these data, tentative forecasts of the future movement and behaviour have been attempted. The sonar surveys are discussed under two separate headings for the sake of convenience.

PRE-SEASONAL SURVEYS

As soon as the Norwegian and Icelandic spring spawning herring leave their respective spawning grounds off the west coast of Norway and the south coast of Iceland in March and April, the dense concentrations usually scatter. Therefore it is very difficult to locate the fish until they have reassembled and summer feeding schooling has begun.

The purpose of the pre-seasonal surveys is therefore to contact or relocate the feeding migrations of herring as soon as possible after post-spawning dispersal. Until sonar this task was almost impossible and the herring industry had to wait and hope that the fish would arrive on traditional grounds off the north coast of Iceland. This usually happened in late June or early July. As soon as the herring entered coastal waters, surfacing of the schools often became sufficiently frequent to make visual location from ships and airplanes reasonably effective. The advantage of locating the herring migrations in advance of the ordinary north coast season is to establish whether the herring were likely to enter their usual summer feeding areas or migrate to other feeding grounds.

During the late 1940's and early 1950's when theories on the migrations of Norwegian herring between Iceland and Norway (Fridriksson, 1944) were being proved through tagging experiments (Fridriksson and Aasen, 1950 and 1952), the interest in locating herring in the open ocean increased rapidly.

During combined hydrographic and biological expeditions on the research vessel *Dana* in 1948 to 1950 in the months of June to August, Danish scientists had located herring in the open ocean north of the Faroe Islands using a vertical echo sounder (Taning, 1951; Taning *et al.*, 1957). Herring samples from these cruises showed them to belong to the same stocks as caught off north Iceland. Similarly, Finn Devold (1950b) also using vertical echo soundings on the M.S. *Vartal* during the summer 1949 located herring concentrations in the open ocean north of the Faroes and south of Jan Mayen.

The real breakthrough in locating herring in the open ocean took place, however, in July and August 1950 when sonar on board the Norwegian research vessel *G. O. Sars* was successfully applied to locate and chart movements of herring concentrations in the Norwegian Sea (Devold, 1950a). During two cruises in July and August 1950 Finn Devold succeeded in locating herring in large areas especially in the mixing areas of the cold East Icelandic current and the warmer Atlantic water. The densest concentrations were found at the eastern borders of the cold water from Jan Mayen and some 200 n mi southwards. Since the location of such large oceanic herring concentrations coincided with the sixth unsuccessful north coast herring season it was only natural that such findings aroused a nation wide interest in Iceland. The necessity for increased research effort into the nature and variations of the summer migrations of the Atlanto-Scandian herring was obvious. Clearly international cooperation was needed.

According to Taning *et al.* (1957) such inter-Scandinavian cooperation in pre-seasonal herring surveys in the Norwegian and Iceland seas was suggested as early as 1948 at a meeting of the ICES North-Western Area Committee. It was, however, first and foremost at the initiative of Dr. Arni Fridriksson that such joint surveys began as a regular annual event in 1952. At the end of the surveys carried out in June 1952 the participating research ships, the *Dana*, *G. O. Sars* and *Maria Julia*, met at Seydisfjördur, Iceland, where a meeting was held during the last week of June, resulting in the first joint report on pre-seasonal herring distribution and environmental conditions. These internationally coordinated pre-seasonal surveys have since been continued for 18 years. The participating countries during the first five years were Denmark, Iceland and Norway. In 1957 the U.S.S.R. joined the project. In 1961 Denmark withdrew permanently and the U.S.S.R. also did not participate for that one year but rejoined the project in 1962. Norway did not participate in 1966 but Iceland, being the most interested country, has participated without interruption throughout the 18 years. During 1952 and 1953 the Norwegian research ship *G. O. Sars* was the only one equipped with sonar and therefore had a great advantage in locating and charting the herring distribution, although herring were also observed by echo sounders on the *Maria Julia* and especially on the *Dana* which traditionally worked in the boundary areas of cold and warm water masses between Iceland and the Faroe Islands. The Icelandic expedition usually covered the area west, north and northeast of Iceland whereas the Norwegian expedition covered the area from the west coast of Norway to Bear Isle–Jan Mayen–Iceland and especially the eastern boundary of the cold East Icelandic current where Devold (1950a) had so successfully located rich herring concentrations in July and August 1950. In June 1954 the Icelandic surveys were carried out on the *Aegir* for the first time but this coastguard vessel had been equipped with a long range sonar set (Kelvin Hughes Whale finder). As the scientific and technical personnel on the *Aegir* gained experience in using the new equipment, the chances of locating herring in the area covered by the Icelandic expedition were enormously increased. In all the pre-seasonal surveys much environmental information has been collected. The cruise plans were thus mainly set up as a series of hydrographic and plankton collection sections cutting across the various water masses and current boundaries

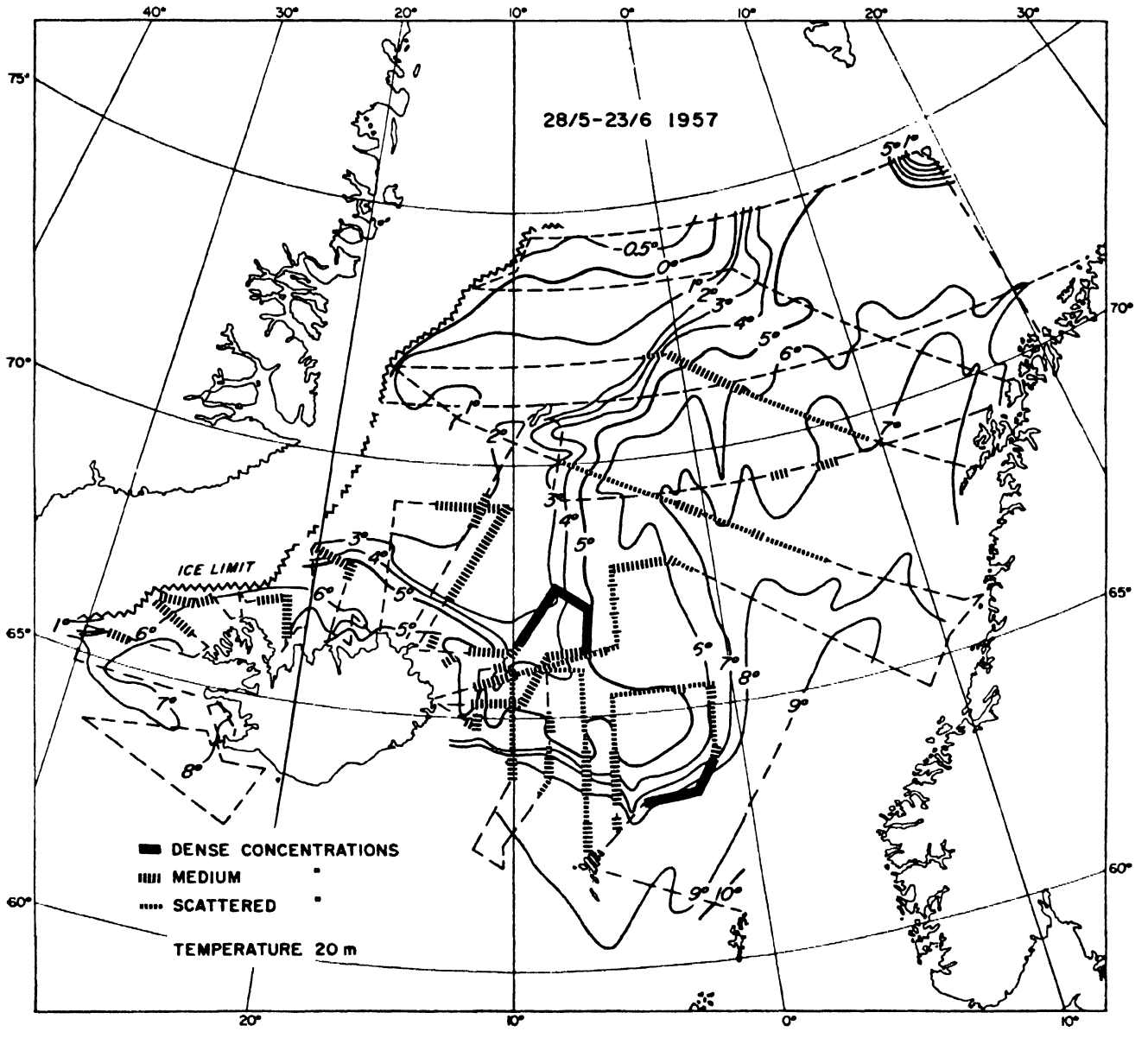

Fig 2. The Joint Norwegian, Icelandic and Soviet Union pre-seasonal surveys in 1957

in the investigated area. Figure 2 shows an example of such surveys for the year 1957. This method has the advantage that a general picture of herring distribution and the environmental factors is simultaneously obtained and the three or four ships participating in the surveys could cover large areas in a relatively short time. Thus a graphic presentation of the pre-seasonal situation was gained. On the other hand, this method did not show the development of the herring migrations in relation to that of the environmental factors. This disadvantage was very clear to the participating scientists and in order to make amendments, two pre-seasonal surveys were planned on the *Aegir* for the first time in 1957 and again in 1959. The first survey in 1959 took place in late May, the other in June. Unfortunately no contact with herring was made partly due to bad weather during the first survey so that the results were mainly valuable only for estimating the development of the environmental factors (Thórdardóttir, 1969) rather than relating these to the progress of the herring migrations. Owing to unavailability of the ships, additional surveys in May and June could not be re-established until 1965.

During the first pre-seasonal cruises in 1952 and 1953 herring was mainly located along the eastern and southern boundaries of the cold East Icelandic current (see also Devold, 1950a and Taning, 1951).

It was therefore supposed that in order to reach the traditional feeding areas north of Iceland, the herring migrations coming from the east would probably have to go around the southern edge of the cold current north of the Faroe Islands and then turn to a northwesterly direction along the southwestern boundaries of the cold East Icelandic current. In 1954, however, a very large number of sonar contacts were made both in the

section Langanes (NE Iceland)–Jan Mayen and on the section east of Langanes within the cold East Icelandic current. The majority of the contacts were small and stayed in relatively warm water above the thermocline. There was some doubt whether these sonar contacts were due to herring but four driftnet samples widely spaced within the cold East Icelandic current gave strong evidence that Norwegian herring could actually migrate across the East Icelandic current in June when a reasonably good thermocline had developed (Jónsson and Stefánsson, 1955).

During the first few years of the pre-seasonal surveys from 1952 to 1957 a clear picture of the herring distribution north of Iceland as well as in the Norwegian sea in June was obtained. Generally, one can say that the herring was scattered over large areas in the region of the East Icelandic current, although the densest concentrations were usually located in the boundary areas of the cold Arctic and the warm Atlantic water masses, especially in the area north of the Faroes and near Jan Mayen (see e.g. Einarsson, 1956). These findings, however, did not give conclusive evidence of the expected herring migrations towards the north coast fishing grounds and the communiqués issued after the joint meetings at the end of June were tentative in their prognosis. The information was, however, important to the herring industry in Iceland. During the long period of low yields in the years 1945 to 1960 it was especially invaluable.

Year by year the boats went further and further off shore because the traditional near-shore fishing grounds were usually devoid of herring concentrations. These ventures were, however, not always successful in the early years mainly due to two reasons. The herring concentrations in the open ocean were often very scattered and the schools seldom surfaced. This last feature was extremely important because the entire purse seine fishery depended on the surfacing of the schools until the development of the Icelandic technique of shooting purse seines around submerged schools with the aid of sonar in the late 1950's (Jakobsson, 1964). During the period about and after 1960 the schooling behaviour of herring in June seemed to change in such a way that the scattered concentrations north of Iceland and in the Iceland–Jan Mayen regions assembled more often into larger fishable schools. As an example as early as the beginning of June 1962 very large schools were located north of Iceland. This change in schooling behaviour, along with revolutionary fishing techniques, changed the nature of the pre-seasonal surveys to a large extent. They became not only a scientific study of herring but were also directly responsible for greatly increased catches in the month of June. Thus, during the period 1952 to 1956 there was no herring fishery off the north and east coast in June. Table 1 shows how the fishery gradually increased during 1957 to 1966 when it had reached 124,000 t at the end of June, i.e. in a period when normally very little fishing had taken place. There can be no doubt that the information obtained from the pre-seasonal surveys was the most important factor contributing to the success of this early start of the herring season.

TABLE 1. CATCHES DURING THE SUMMER NORTH AND EAST COAST HERRING SEASON PRIOR TO 30 JUNE EACH YEAR

Year	*Catch in 1000 t*	*First date of catches*
1950		3 July
1951		28 June
1952		1 July
1953		27 June
1954		4 July
1955		4 July
1956		26 June
1957	19.6	19 June
1958	11.1	17 June
1959	8.8	19 June
1960	39.0	17 June
1961	21.5	13 June
1962	14.6	19 June
1963	32.1	8 June
1964	81.0	31 May
1965	123.3	24 May
1966	124.3	12 May
1967	45.2	26 May

The success of the previous June surveys as well as the unusual ice situation prompted us in 1965 to re-establish the system of repeated surveys in May and June in order to gain more knowledge of the development of the herring environmental relationships in spring and early summer. No herring was located west and north of Iceland during the 1965 May survey. It was not until we came east northeast off Langanes that we located some herring near the eastern boundary of the cold East Icelandic current. Further south and southwest we located large numbers of good schools with the results that the first boats arrived in this area a few days later and the herring summer season began and, as shown on Table 1, the catch to the end of June amounted to 123,000 t.

Before the May survey was finished we called not only the fishing vessels to the herring areas but also our scouting vessel the *Hafthor*, which soon observed that the herring concentrations were moving in a northerly and even northeasterly direction during the first days of June instead of the more usual westerly or northwesterly direction. Such was the effect of the Icelandic survey in May 1965 that the traditional pre-seasonal survey in June began two or three weeks after the beginning of the season. The direct effect of the June survey on the herring fishery in 1965 was, however, very important because the fishermen did not realize how quickly the herring migrations moved north and the fishery was rapidly decreasing. We then relocated very dense concentrations of herring much further north, as shown in fig 3.

Environmental studies have always been an important and integral part of the pre-seasonal surveys. The author has, in a recent paper, (Jakobsson, 1969 Icelandic version, 1970 English version) discussed the effect of temperature changes on the herring migration in the Norwegian sea. As shown, for example, by Jónsson and Stefánsson (1955) and Einarsson (1956), the herring often migrate in small scattered schools across the East Icelandic current in late May and early June especially if a relatively warm surface layer has developed above a sharp thermocline. In later years, especially since 1965, the increased proportion of polar water in the East Icelandic current (Malmberg, 1967; Malmberg and Stefánsson, 1969) seems to have brought the sea tem-

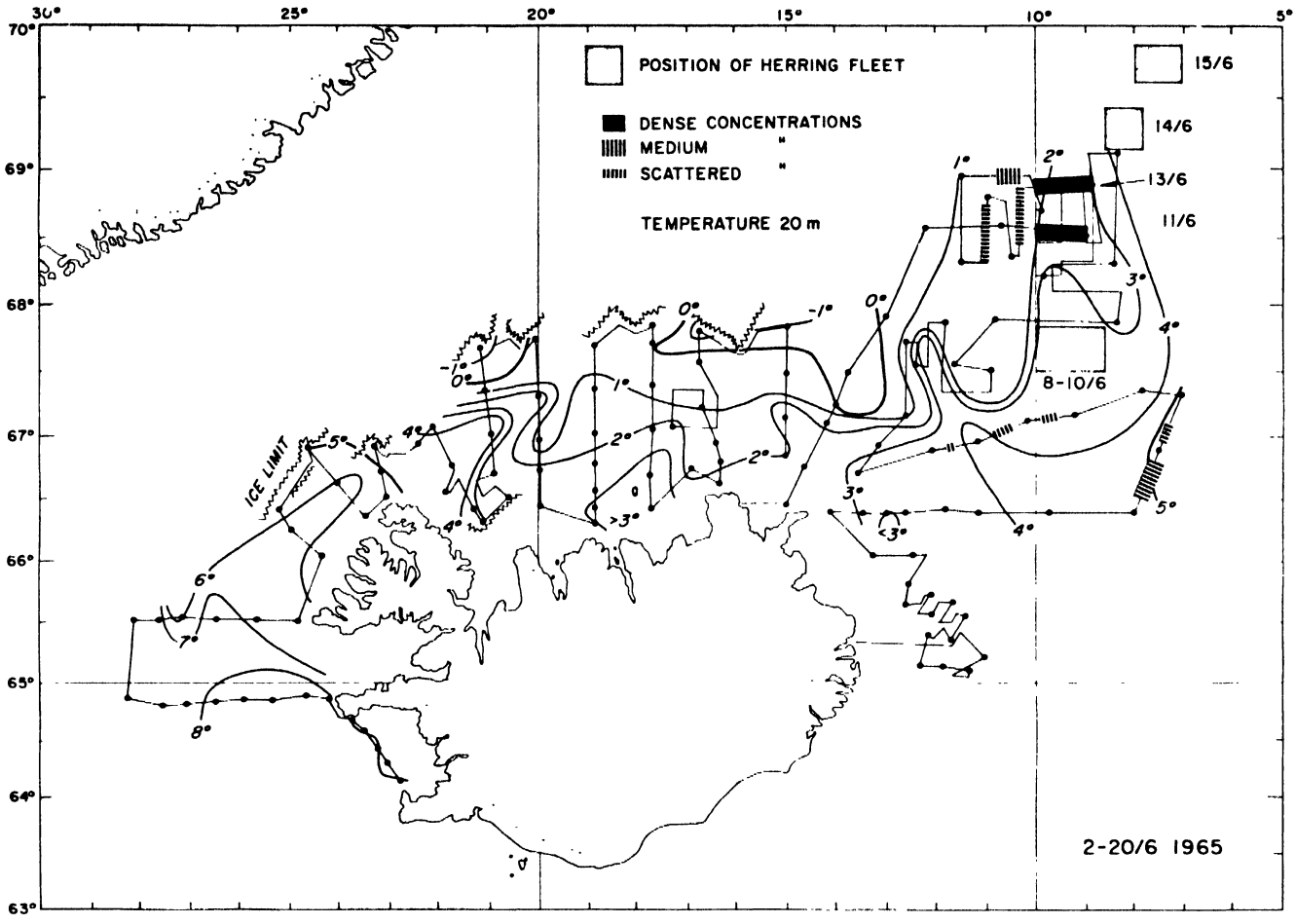

Fig 3. Temperature at 20 m and herring distribution in June 1965

perature in this area below a tolerated threshold level and the herring in May to June 1965 entered the cold water and soon turned north and northeast in search of more viable environment. In other years when the sea temperature is above such a threshold level the temperature has less apparent effect on the herring distribution. Then the feeding conditions in the late spring and early summer seem to have a greater effect. As an example one can mention the conditions in 1962 when *Calanus finmarchicus* concentrations were very dense off north Iceland in June (Anon., 1964) and large herring schools were located there as early as 4 June. In 1964 the *C. finmarchicus* concentrations were very far off shore and the distribution of the herring concentrations were correspondingly found in far off-shore areas. Thus the distribution of the herring may in some years be mainly affected by one environmental factor but in other years the apparent effect of a different environmental factor may be of more importance.

SEASONAL HERRING SONAR SURVEYS

The purpose of the seasonal herring sonar surveys which started in 1954 was first to directly assist the herring fleet in locating fishable concentrations. In addition considerable environmental research has been carried out to improve understanding of the mechanism of herring migrations and schooling behaviour during the herring seasons.

During September 1954 two sonar surveys with *Aegir* were carried out off southwest Iceland under the leadership of the author.

In 1955 the *Aegir* was equipped with two dories and a purse seine and successful fishing of submerged schools took place (Pálmason, 1955; Einarsson, 1956). In 1956 a chartered fishing vessel equipped with an echo sounder with a manually-operated sonar acted as a support vessel for the *Aegir* and in 1957 the support scouting vessel was equipped with a more sophisticated sonar. In 1959 the state owned ship *Fanney* was equipped with a new 1,500 m range sonar and was used as a support vessel with the *Aegir* until 1964. During the years 1962 to 1967 there were two support scouting vessels working with the *Aegir* during the height of the season.

Looking back one can see that the herring search technique has developed and changed considerably. Thus the seasonal surveys in 1954 were more or less based on the pre-seasonal survey pattern where care was taken to cruise across different water masses in a systematic way in order to get more or less general information of the area covered.

The tactics adopted in later years or since 1957 consisted of general off-shore surveys in order to get an

estimate of the herring concentrations in adjacent areas and detailed surveys of the more traditional fishing grounds if the environmental factors and herring concentrations indicated that such detailed investigation was feasible. In most cases the densest herring concentrations during the years 1957 to 1966 were located at, or just outside, the continental shelf in the boundary areas of warm and cold water masses. Furthermore, the concentrations usually extended along the current boundaries but had a less extensive distribution pattern in other directions. It was found that a good search strategy was to follow a grid pattern wherein the ship cruised at right-angles to the current boundaries or the general profile of the continental shelf. In this way the danger of passing any dense concentrations of herring without detection was considerably diminished. It should also be noted that during the period after 1956, and especially since 1961, the opportunities for detailed studies of herring concentrations were greatly increased due to the additional scouting vessels. These additions to the herring search organization were in a way counterbalanced as the fishing areas moved farther and farther off shore until the fishing became a true oceanic fishery in 1967 and 1968. Then the majority of the catch was taken more than 500 n mi from the nearest Icelandic ports (figs 4 and 5).

Sea temperature and herring food, as observed in our sampling instruments, have played a very large part in the tactical planning of the seasonal herring sonar surveys. Thus the pre-seasonal surveys are planned in relation to the hydrographical features of the Iceland and Norwegian seas. Similarly, the location of the boundary areas between warm and cold water masses directly influence the tactics of the seasonal surveys.

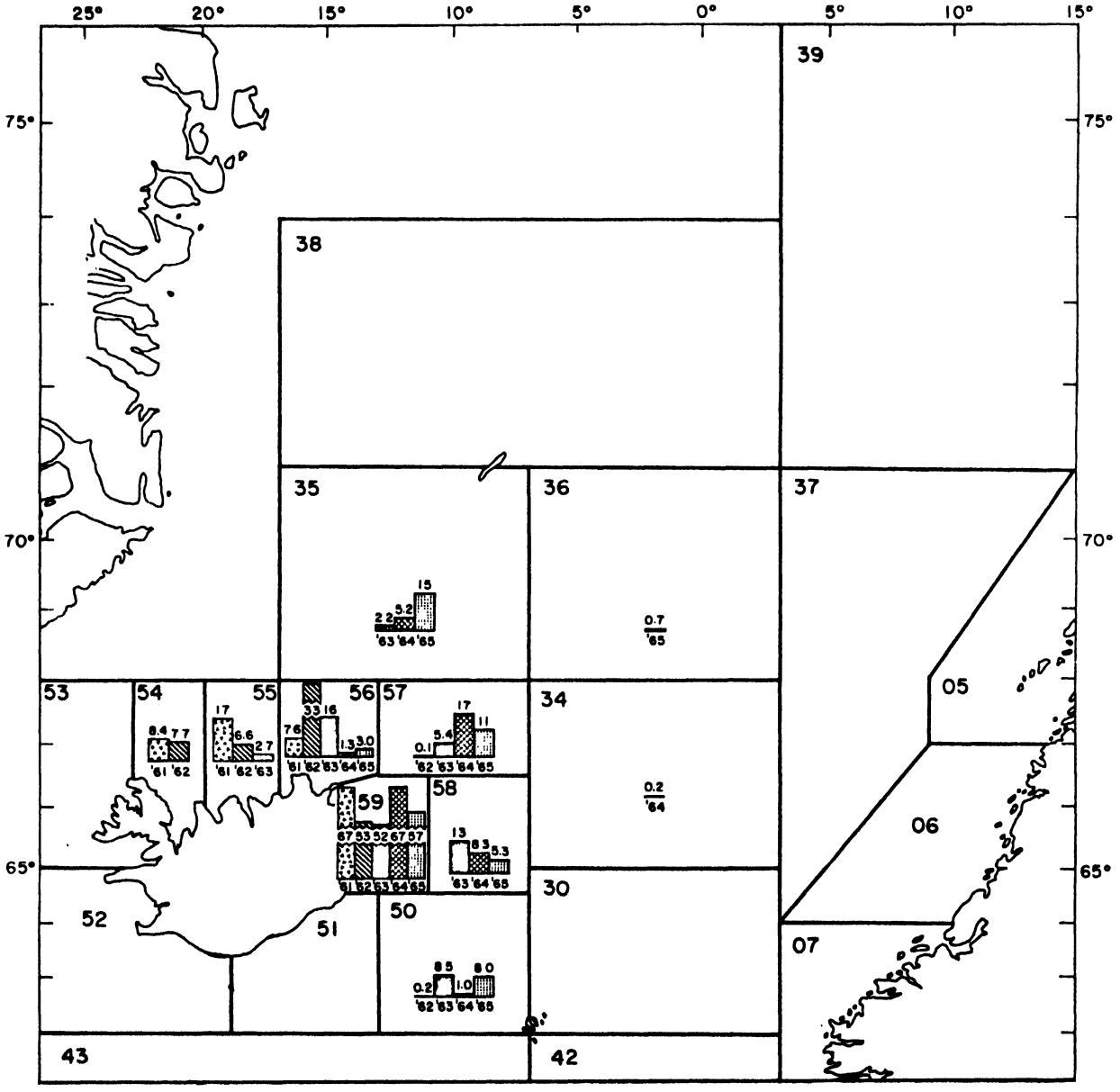

Fig 4. Percentage distribution of the Icelandic herring catches in 1961 to 1965

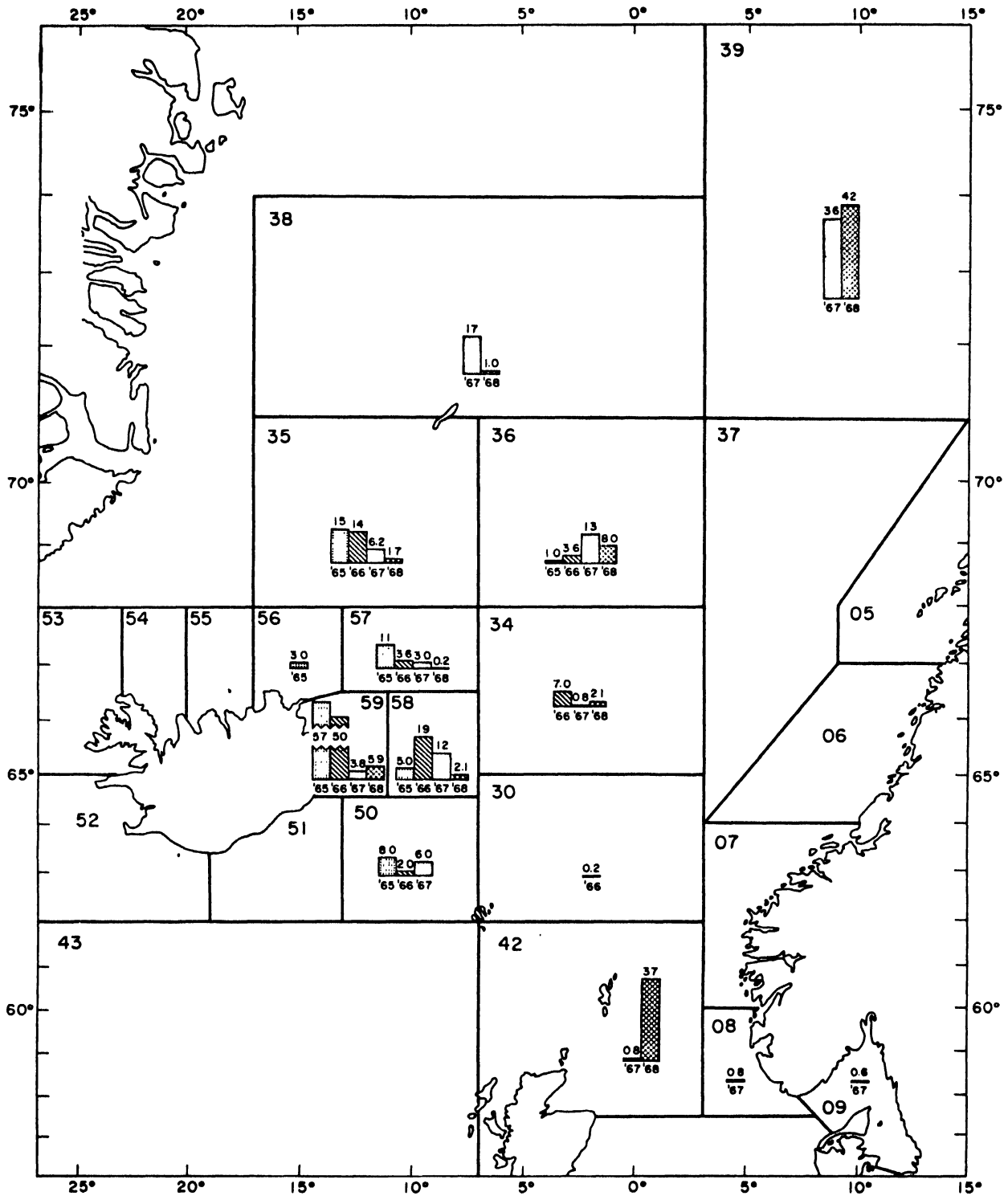

Fig 5. Percentage distribution of the Icelandic herring catches in 1965 to 1968

Thus Jakobsson (1963) compared the relative success of herring fishing off the north coast of Iceland during the second half of the season, i.e. the catch after 31 July, with the changes in sea temperature from one year to another. This comparison tended to show that high sea temperature, i.e. strong influx of Atlantic water in mid-summer, happened in years when the herring fishery was relatively poor off the north coast of Iceland in August. During the long period of low yields of the Icelandic north coast season 1945 to 1960 there were two exceptionally "cold" years, i.e. 1949 and 1958. In 1949 herring were located as late as September off the north coast when considerable fishing took place but bad weather and irregular surfacing of the schools during

Forecasting Purse Seine Fishing Conditions in East China Sea

by E. Ura and I. Mori

Prévisions des conditions de pêche à la seine coulissante dans la mer de chine orientale

La pêche à la seine coulissante du maquereau et du chinchard représente l'une des principales pêcheries dans les eaux voisines du Japon. Les prises annuelles sont d'environ un million de tonnes. Depuis 1959, pour assister la flottille des seineurs, la Préfecture de Nagasaki a fourni des prévisions hebdomadaires et semestrielles sur les possibilités de pêche. Les informations contenues dans ces prévisions comprennent la région, la taille du poisson et les quantités disponibles. Des prévisions à court terme sont établies à partir des informations transmises par la flottille commerciale et des prospections mensuelles effectuées par les navires de recherche. Elles fournissent des renseignements sur la salinité, la clarté de l'eau pour l'attraction par la lumière, la température et la localisation des zones limitrophes des courants. Le lieu de pêche le plus productif découvert par un navire de recherche a été localisé en Mer de Chine orientale, au confluent du Kuroshio et de la Mer Jaune. L'évaluation des stocks de poissons par les navires de recherche comporte l'emploi de lampes d'attraction; toutes les fois que des concentrations intéressantes sont localisées, l'information est communiquée par radio à la flottille.

El pronostico de las condiciones de la pesca con redes de cerco de jareta en el Mar de la China oriental

La pesca de caballa y jurel con redes de cerco de jareta es una de las pesquerías más importantes en las aguas cercanas al Japón. La captura anual es de un millón de toneladas aproximadamente. Desde 1959, la Prefectura de Nagasaki ha dado pronósticos semanales y semestrales de las posibilidades pesqueras para ayudar a la flota de tal pesquería. La información facilitada en los pronósticos comprende la zona, el tamaño de los peces y la cantidad existente. Los pronósticos a corto plazo se hacen basándose en la información proporcionada por la flotilla comercial, y los reconscimientos efectuados mensualmente por buques de investigación. Estos proporcionan información sobre la salinidad, claridad del agua para la pesca mediante la atracción con luces, temperatura del agua, y situación de las capas limíte de las corrientes. El caladero más productivo encontrado por un buque de investigación se hallaba en el Mar de la China oriental, en la confluencia de la corriente del Kuroshivo y el Mar Amarillo. En la estimación de las poblaciones de peces, los barcos de investigación se emplea también luces de atracción, y siempre que se localizan buenas concentraciones esta información se facilita por radio a la flota.

MACKEREL and horse mackerel are an important resource found all along the coast of Japan and in neighbouring seas. The annual total catch is 1,110,000 t, i.e. 21 per cent of the total fish catch in Japanese waters; 46 per cent of the total is caught by large purse seine boats.

In Nagasaki Prefecture, these two fish species constitute 41 per cent of the total catch (500,000 t) and 88 per cent are taken by large purse seiners (Tables 1 and 2).

Thus, Nagasaki Prefecture, because of the importance of this fishery, has been giving weekly forecasts since 1959.

PURSE SEINE FISHERY IN EAST CHINA SEA

The purse seine fishery of Nagasaki Prefecture has been enlarging its operations since 1945 when it began to

TABLE 1. WEIGHT IN TONS OF SPECIES CAUGHT BY PURSE SEINE FISHING IN THE EAST CHINA SEA AND WEST JAPAN SEA

Source: Ministry of the Agriculture and Forestry in Japan

Year	*West Japan Sea and East China Sea Total catch*	*East China Sea (Except Quelpart Is. region)*			
		Total catch	*Horse Mackerel* (Trachurus)	*Mackerel* (Scomber)	*Horse Mackerel* (Decapterus)
1959	317,108	43,358	27,814	14,630	362
1963	329,146	129,224	114,074	11,344	2,585
1965	496,117	224,864	191,644	27,235	1,920
1967	362,919	178,832	75,470	36,299	63,652

TABLE 2. THE TOTAL CATCH IN TONS OF MACKEREL AND HORSE MACKEREL AND THE CATCH BY PURSE SEINES IN 1967, IN THE ADJACENT WATERS OF JAPAN AND NAGASAKI PREF.

The total catch of Japan was 5,227,625 t and that of Nagasaki Pref. 496,878 t

Species	*Total catch in Japan*	*Catch by purse seine*	*The total catch in Nagasaki Pref.*	*Catch by purse seine*
Horse mackerel (*Trachurus*)	327,878	223,041	108,734	89,509
Horse mackerel (*Decapterus*)	95,474	77,174	38,784	38,244
Mackerel (*Scomber*)	687,474	215,524	55,222	50,576
Total	1,110,826	515,739	202,640	178,329

TABLE 3. COMPOSITION OF A TYPICAL PURSE SEINE FISHING UNIT

Boats	*Tonnage*	*Horse power*	*Number of boats*	*Number of crew (each boat)*
Net boat	80	400–500	1	35
Light boat	35	150–180	2	8 per boat
Searcher boat	35	150–180	1	8
Carrier boat	100–200	300–600	3	9–12 per boat

develop quickly through use of sonar, large fishing boats and gear, and changed from sardine fishing to mackerel and horse mackerel fishing. This is attributable, among other things, to low availability of sardines since 1952. That decline prompted resource assessment surveys to find new grounds. These surveys were conducted by the research ship owned by the Fisheries Experiment Station and purse seine fishing boats took part with enthusiasm. In 1958, a new fishing ground was discovered in the East China Sea and commercial operations began there in 1965, making it a major fishing ground.

A typical purse seine fishing unit for mackerel and horse mackerel has seven boats, including the netting boat as its nucleus.

Gear and method of fishing

The net is made of tetoran, twine size 210/21, its construction is rectangular, measuring 700 m in length and 300 m in depth.

The operation begins in the evening with all boats taking part in search for schools with sonar and echo sounders. When schools are detected all boats stop, the light boats anchor and turn on the fish-luring lights (10 kW). The time required to attract fish depends upon seasonal fishing grounds and behaviour of schools, and lies usually between 2 and 3 hours after which fishing begins. One end of the net is given to the carrier, and the seine is set clockwise around the fish luring boat, and is pursed and hauled. The time required for the catching operation varies according to the catch, forces of winds and currents, etc., usually taking about 3 hours. Normal catches are 20 to 50 t.

Fishing season for mackerel and horse mackerel is:

May-November: off to the west of the Goto Islands.
November-December: Yellow Sea.
January-June: East China Sea.

Recently, however, catches have been poor on the first two fishing grounds. Thus, the major ground is now East China Sea, in the area where the Kuroshio Current and the Yellow Sea meet, and the new fishing ground, discovered in 1968 off China has similar oceanographic conditions (fig. 1).

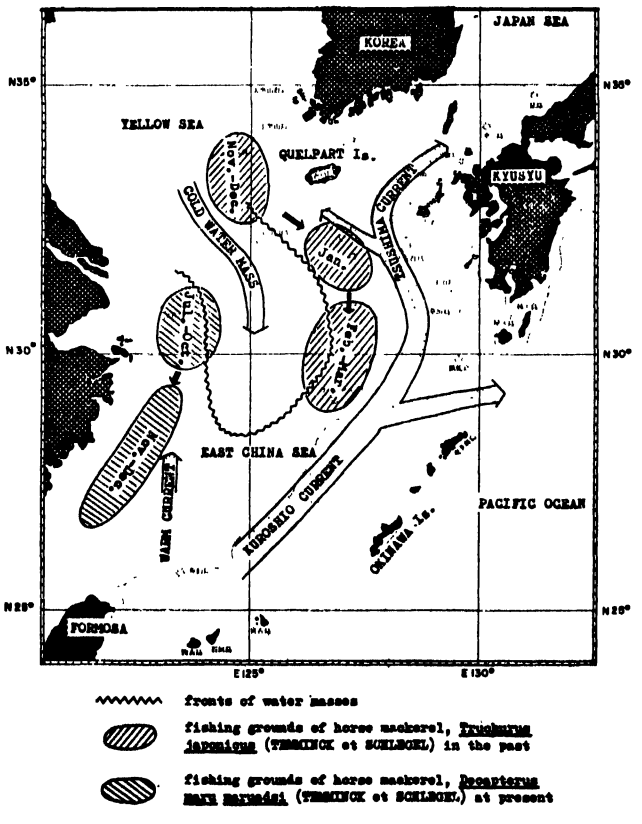

Fig 1. Schematic chart of the hydrographic structure of the East China Sea and the purse seine fishing grounds

Forecasting of fishing conditions

There are two types of forecasting for the purse seine fleet: (a) long-term forecasting, (b) short-term forecasting.

The former (a) is conducted by holding meetings twice a year, organized by the Seikai Regional Fisheries Institute and the fishing experimental stations of the prefectures facing the western area of the Sea of Japan and the East China Sea. It releases 6-month forecasts of fishing periods by fishing ground, sizes of fish, and the quantity available. The Nagasaki Prefectural Fisheries Experiment Station gives only short-term forecasts.

The data for short-term forecasting include the following:

(1) Results of commercial fishing vessel operations such as location of fishing grounds, kinds, size, and quantity of fish caught, which are supplied by purse seine boats (by radio) operating in offshore areas.
(2) Information on dates of operations, location of fishing grounds, fish catch by species, sea conditions, fish-luring conditions, depth of the areas where schools are found, which is obtained from vessels landing fish at the Nagasaki fish market.
(3) Results of measurements of mackerel and horse mackerel landed at the Nagasaki fish market.
(4) Results of oceanographic surveys conducted by the research ship once a month. The Western Japan Sea condition report is released by the Nagasaki Marine Observatory once every 10 days.

Preparation and announcement

On the assumption that similar oceanographic and fishing conditions will allow similar catches of fish, weekly forecasts are prepared based on: catches of mackerel and horse mackerel; distribution of and movements of fish concentrations; movements of the Kuroshio Current, the Tsushima Current and the Yellow Sea; different water temperatures and current boundary location: comparison between normal years and preceding years is also taken into consideration.

Weekly forecasts are announced every Saturday. They are not restricted to the distribution of printed matter to the purse seine fishing boats only, but they are also broadcast to the general public and printed in local newspapers.

Searching for fish by research vessel

Through research so far conducted, it has become clear that the new fishing ground in the East China Sea is at the meeting point of the Kuroshio Current and the Yellow Sea. As favourable conditions are necessary for fishing grounds to be productive, the Experiment Station conducts research in the more promising areas three times a year. This research is correlated with the environment of the fishing grounds (such as temperature, salinity, etc.), and the distribution of schools of fish located with sonar and radar. When large schools are found, fish-luring lights are operated to estimate the quantity. After confirmation of the species by catching trials the results are given directly to purse seine boats or by radio.

Research is not conducted on known fishing grounds as the purse seine boats know them well.

Methods of Discovering and Assessing Fish Concentrations

by Y. B. Judovitch

Méthodes de détection et d'évaluation des concentrations de poissons

La détection et l'évaluation qualitative et quantitative des concentrations de poissons ayant une valeur commerciale est le rôle d'un service spécial de prospection des pêches. Dans des conditions stables la localisation de ces concentrations peut demeurer la même ou varier seulement légèrement d'une année à l'autre pour les saisons correspondantes. Des changements brusques peuvent aussi survenir, en rapport éventuellement avec des modifications des conditions océanographiques, qui rendent assez difficile la détection du poisson. Une détection rationnelle du poisson requiert le mise en oeuvre de recherches complexes et la conduite d'une série d'opérations. Elle porte notamment sur l'océanographie, l'écologie, la détermination des espèces, les évaluations quantitatives, les études du comportement du poisson, etc. Sur ces bases, on établit des prévisions à court terme et à long terme de la répartition du poisson et des conditions de pêche en vue d l'orientation de la flottille de pêche.

Metodos para localizar evaluar concentraciones de peces

La localización de concentraciones de peces de importancia comercial y la evaluación cuantitativa y cualitativa de las mismas es tarea de un servicio especial de reconocimiento pesquero. En condiciones estables, la ubicación de las concentraciones de peces importantes desde el punto de vista comercial puede permanecer inmutada o variar sólo ligeramente de un año a otro, en la misma estación. Pero pueden producirse también cambios bruscos, debidos, por ejemplo, a variaciones de las características oceanográficas y, en ese caso, la localización de los peces puede resultar tarea difícil. La localización racional de los peces exige una investigación compleja y toda una serie de operaciones, que incluyen oceanografía, ecología, identificación de especies, estimaciones cuantitativas, estudios sobre las reacciones de los peces, etc, basandose en lo cual se preparan observaciones a corto y a largo plazo, que sirvan de guía a la flota pesquera, sobre la distribución de los peces y las condiciones de pesca.

FINDING commercial concentrations of fish and evaluation of their composition and quantities is a task entrusted to the fishing reconnaissance service of the fishing industry and is intended to increase the efficiency of the fishing fleet.

When organizing commercial fishing reconnaissance one must take into account the general properties of a particular ground, the behaviour of fish and especially the species sought. This is done by confining the search only to areas most favourable for fish.

The promising areas may happen to be rather extensive which calls for the most efficient methods and technical means to be used if searching is to be successful. In addition one must take into consideration that commercial concentrations of fish and factors influencing their distribution change continually.

Fish searching is usually classified into operational and long term. In many cases, however, the technical means and methods involved in finding fish both during operational and long-term searching are similar and therefore no clearcut division between them is possible though their aims are definitely different.

Long-term searching is concerned with opening up new areas for exploitation or for catching new species within known areas.

Operational fish searching is confined to a locality where actual fishing is underway. It supplies the fleet with information making the operation of fishing vessels as efficient as possible. The search of commercial concentrations of fish includes making up forecasts for distribution of fish in designated areas, together with details of results of hydrological investigations and fore-

seeable amount of schools of fish, echo surveying, identification of general areas which might favour the formation of commercial concentrations of fish (a preliminary search) and detailed searching of areas which favour concentrations of fish (detail search). The forecasting of fish distribution is based on the data obtained during many years.

SEARCH METHODS

The areas where most fish concentrate in commercial quantities are rather constant. However, the fishing charts testify that areas of concentrations may shift a few hundred miles depending on the season. Therefore, accuracy of forecasts for fish distribution for each particular locality and commercial species varies within a distance between the extreme positions of fish concentrations occurring for a number of years during the respective seasons.

Stability of seasonal distribution of commercial concentrations is accounted for by a relatively constant distribution of nutrients and hydrological parameters. Therefore, the preliminary forecast for the distribution of fish can be made more accurate if the hydrological forecast and the forecast of distribution of nutrients have already been made. The forecast on the distribution of fish can be pinpointed by foreseeing the amount of fish in a school, i.e. with all other conditions equal, the commercial concentrations spread over larger areas when the schools are more numerous.

As soon as the area of probable concentration is detected the echo surveying of it is performed which includes hydrological, hydroacoustical, visual and hydrobiological observations, as well as test fishing. Echo surveying is a science based prerequisite for search and survey operations.

The chart of search routes (tracks) can be of different patterns, such as parallel, rectangular, oblique, uniform and non-uniform tracks (fig 1). If the fish are spread uniformly over the area, the most reliable tracks, with other conditions equal, will be those of parallel and mixed pattern of tracks. If the fish spreads randomly, the tracks should be closer spaced where the habitation of fish seems more likely (the zones of convergence, the zones of considerable temperature gradients and salinity, deeper zones, banks, etc.). The tracks during the echo surveying are spaced according to how the fish are spread. When searching for winter concentrations with fish gathering in dense stocks within a limited area, it is essential to be aware of the hydrological conditions, therefore, the distance between the tracks should be not more than 25 to 30 mi. Only in well surveyed areas where the hydrological elements (temperature, salinity, oxygen, etc.) are rather constant, the track spaces may be extended up to 40 to 45 mi.

When searching for fish on a feeding run, the track spaces may be up to 80 to 100 mi with the tracks as long as 180 to 200 mi.

Test fishing is normally done where there are detected fish stocks or runs, concentrations of birds or marine animals.

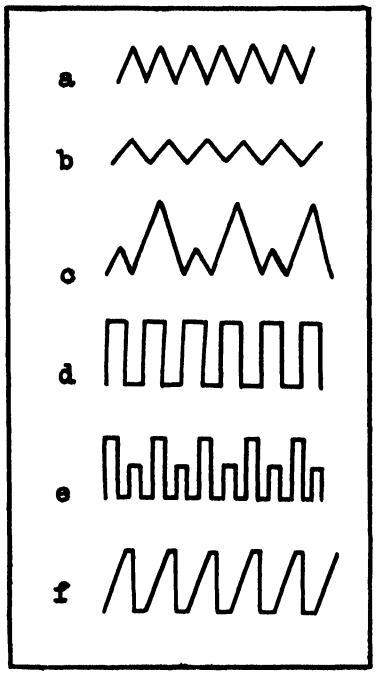

Fig 1. Network types of search tracks
a, b, c = oblique tracks; d, e = parallel tracks; f = mixed tracks

In preliminary echo surveying, trawling is performed every 15 to 30 mi. Hydroacoustic and visual observations should be continuous. The tracks are laid out so that they intersect the streams, the depth zones and the general direction of isobaths. This allows plotting of charts for water mass distribution, currents, salinity, oxygen and nutrients (plankton and benthos).

Proceeding from the above data and knowing the biological behaviour of fish, the areas are identified which are favourable for commercial concentrations. Those areas are then subjected to a pinpoint survey with the aid of hydroacoustic fish finding instruments and gears.

For a detailed survey, the spaces between the tracks are selected so as to locate all the commercial concentrations, or the larger part thereof, which are in the search area.

$2D + r$

D = detection range

r = minimum size of commercial fish concentration

The bottom fish concentrate in commercial quantities where the streams converge, at banks and on the slopes of underwater canyons. In high latitudes bottom fish concentrations are often observed in the core of warm water. Since such concentrations not infrequently run along the isobaths, the search tracks are laid out in a pattern to intersect them. During search, a detailed chart is made up which includes the identification of depths, bottom description and composition of the benthos. The sections best for trawling are plotted so as to stand out clearly on the chart.

Trawling is done every three to five miles. In some instances the spaces between the drags are reduced to narrow increments.

For detection of pelagic stocks, a good practice is to use airborne visual observations. If the water is transparent enough the fish stocks will be observable to as deep as 25 m.

The forecasting search and surveying involve much difficulty inasmuch as the areas to be searched are inadequately investigated from the fishery standpoint. This is why the preparation of a route assignment is preceded by compilation of a hydrological and metereological survey for a search area which is based on data available, finding out the current pattern, collection of data on water temperature distribution and sea-bed contour.

When working out the route assignment, making up the plan and patterns for search, method of search comparisons may prove to be of much use in comparing the general data available for an area where the commercial fleet has been fishing, with the data for the new area where fishing is to be started. If the areas compared reveal similarity, the conditions existing for abundance of fish and their behaviour may be expected to coincide.

There are, of course, no areas which coincide exactly on all data, nevertheless the method of search comparison allows some regularities to be foreseen in how the commercial fish spread in their behaviour, depending on the environmental factors. Whether a comparison area is successfully selected which coincides with the area of future search depends on the know-how of the commercial search people and on how well the area of future search has been investigated.

When selecting a reference area, the areas to be compared must be of identical geographical zones and of identical oceanagraphic characteristics: current conditions sea-bed relief, grounds, depths, temperature and salinity. When searching for pelagic fish, much attention in selecting the reference area should be paid to the fact that the nutrients and temperature conditions in the pelagic zone must coincide. When searching for demersal fish the coincidence of depths, sea-bed relief and ground character, as well as temperatures at the bottom and the currents in the respective time periods are most important.

For search of a few commercial species that share one area it is possible to select either one or two, or more, reference areas (one for bottom fish and one for pelagic fish).

The comparison methods allow a detailed investigation of only some of the sections of a new area which seem more promising. The size of such area sections, the distance between the search tracks and the number of test fishing trials differ from area to area. They are determined by the standard achieved in commercial surveying methods, knowledge of how commercial concentrations originate and disintegrate, other conditions being equal.

Once concentrations are detected, the reconnaissance operations are performed, i.e. the outlines are drawn, the number and composition of schools are estimated and the vessels directed to the detected localities. As to their structure, the commercial concentrations may be of a school type, or a thinly concentrated and mixed type (fig 2). The methods applied for assessment of fish quantities in a concentration varies with its position in the water column and its density.

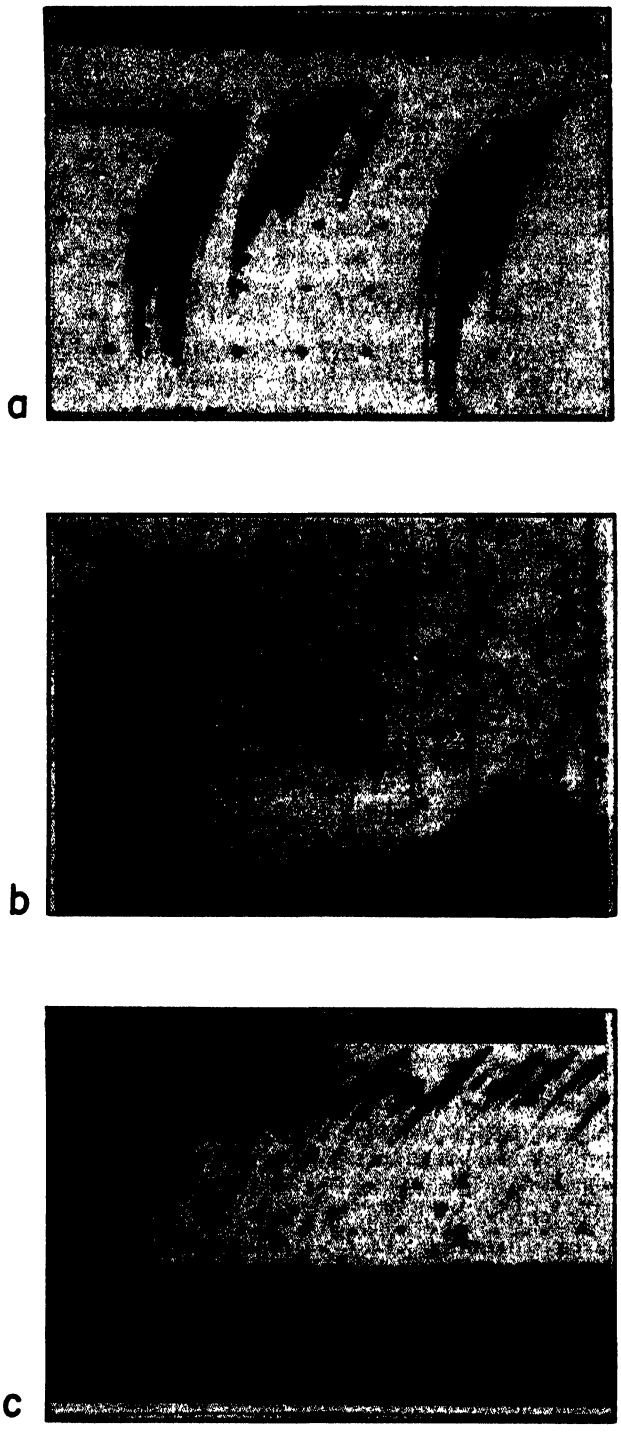

Fig 2. Echograms showing commercial fish concentrations a = schools; b = single fish and small schools; c = mixed schools

Irrespective of the kind of concentration (bottom, demersal or pelagic fish), it should be plotted. Depending on the type of a concentration, the plotting can be done either by two search tracks (crosswise), or by a network of search tracks that intersect the area where a concentration of fish is supposed to be. When plotting the concentration, the vessel travels along the section until the hydroacoustic instruments can "see" the fish or the fishing gear can catch it.

QUANTITATIVE ASSESSMENT METHODS

The quantitative estimation for bottom concentrations of fish is made up according to the test hauls. The most popular method used for test hauls of bottom concentrations is trawling. The trawling results may be considered comparable if the trawlings were done within the periods when the fish behaviour is normal. When some definite and regular changes in catch rates are observed within a day, the trawling time should be selected taking into consideration those changes.

Assuming that the fish spread uniformly over the trawling area the value of the possible catch for a concentration (P) can be found from the equation:

$$P = \frac{F}{f}(\bar{q} \pm \varepsilon) \tag{1}$$

F = the outlined area of concentration

f = area of single test trawling

$\bar{q}$ = mean catch per haul

ε = determination error for $\bar{q}$

If the catches within the outlined concentration vary appreciably, auxiliary plots should be drawn connecting the points of different catches and selecting them so that between those plots the catch amount does not vary more than two or threefold. The amount of possible catches should be found by summing up the values of possible catches for areas

$$F_1, F_2 \ldots, F_n$$

included between the intermediate plots.

Used as a criterion for assessment whether the equation (1) is applicable is a catch variation coefficient C.

$$C = \frac{\sigma}{\bar{q}} 100 \text{ per cent}$$

where σ = the standard deviation of the catch value per unit trawl operation (tow) from the mean value

$\bar{q}$ = mean catch per trawling (tow).

If the value of $C \leq 100$ per cent, the possible catch of fish within the concentration will be found from the equation (1). Table 1 gives an example for treating search data to assess the quantity of a bottom concentration.

$$\bar{q} = \frac{\Sigma q}{n} = \frac{91}{13} = 7 \text{ centners (350 kg)}$$

$$\sigma = \sqrt{\frac{\Sigma(q-\bar{q})^2}{n-1}} \approx 2.8 \text{ centners (140 kg)}$$

$$C = \frac{2.8}{7} \cdot 100 = 40 \text{ per cent}$$

$$\varepsilon = t\beta \frac{C}{\sqrt{n}}$$

where $t\beta$ = factor depending on confidence probability and the number of degrees of freedom $(n-1)$

For the above example with $\beta = 0.9$, $n-1 = 12$, $t\beta = 1.77$, hence

$$\varepsilon = 1.77 \frac{2.8}{3.5} = 1.4 \text{ centners (70 kg).}$$

The amount of catch per unit trawling with a probability of 0.9, is:

$$q' = 7 \pm 1.4 \text{ centners.}$$

Assuming $\frac{f}{F} = 0.0001$ the amount of possible catch for a concentration is:

$$P = 70000 \pm 14000 \text{ centners.}$$

To obtain finer results (to reduce the confidence interval) more test trawlings are to be done.

The total amount of fish in a concentration P_0 can be found from the equation:

$$P_0 = \frac{1}{\rho} P \tag{2}$$

where ρ = trawl capacity factor is:

$$\rho = 1 - \frac{V_0}{V_{tr}} \tag{3}$$

where V_0 = minimum velocity with no catch,

V_{tr} = velocity of search trawling.

Determining the sizes of thinly spread pelagic concentrations and their quantitative estimation involves many difficulties and takes considerable time since such concentrations occupy large areas with quickly changing boundaries.

The thinly spread concentrations are outlined with the aid of an echo sounder.

In determining the vertical extension of a concentration within intricate curvilinear surfaces, it should be treated as a plate of a constant thickness whose volume is found by multiplying the concentration area (F) by vertical extension (h). The areas are calculated with the aid of a planimeter or a transparent graph paper. The vertical extension is to be determined according to the echographs as a mean arithmetic of different points within the concentration thickness.

The total amount of fish within the concentration P_0 is found from the equation:

$$P_0 = \rho F h = \rho V \tag{4}$$

where ρ = concentration density, i.e. the content of fish per one unit of concentration, by weight or in pieces.

V = volume of concentration.

TABLE 1. TREATMENT OF SEARCH DATA IN QUANTITATIVE ASSESSMENT OF BOTTOM CONCENTRATIONS

No.	*q Catch/tow in centners (50 kg)*	*Deviations from mean* $q-\bar{q}$	*Deviation square* $(q-\bar{q})^2$
1	13	+6	36
2	7	0	0
3	5	−2	4
4	7	0	0
5	7	0	0
6	4	−3	9
7	6	−1	1
8	12	+5	25
9	8	+1	1
10	7	0	0
11	3	−4	16
12	7	0	0
13	5	−2	4
	$\Sigma q = 91$		$\Sigma(q-q)^2 = 96$

The value of ρ is found from the equation:

$$\rho = \frac{q}{V_c \rho} \tag{5}$$

where q = amount of test catch

V_c = volume of that part of the concentration which has been covered

ρ = factor of catching capacity of gear used in trawling.

The density of the concentration can also be determined by underwater visual observations and underwater photography. In thinly concentrated schools of herring the density is 1 to 5 g/m³. In the over-winter period the density of the herring schools are 50 to 200 g/m³ with a considerable increase during spawning. An instance has been recorded of finding schools with a density of up to 130 kg/m³. The density of thinly concentrated Alaska pollack schools may come up to 30 to 50 g/m³, etc.

If the distance between fish in a concentration is in excess of the echo sounder minimum resolution capability and each fish is spotted on the echograph as an individual dot (fig 2b), then the hydroacoustic means are used for quantitative assessment of these thinly concentrated pelagic and demersal schools. To determine the amount of fish, the concentration is outlined. The echographs are used for determining the quantity of fish in a volume of water (Vk) probed within a certain known period inside the concentration outline. Then the density of fish is:

$$\rho = \frac{Nk}{Vk} \text{ pieces per 1 m}^3 \text{ concentration} \tag{6}$$

The volume of water probed is found from the equation

$$Vk = V t \left(\frac{Z_1 + Z_2}{2}\right) h \tag{7}$$

where V = vessel speed, m/min

t = probing period

Z_1 and Z_2 = cross section of the echo sounder beam at upper and lower edges of the concentration

h = mean thickness of concentration layer during echo sounding

After the calculation of concentration density is done, the lines of the same density are then drawn at different points. The quantitative assessment of each concentration section is found from the equation:

$$Ni = Vi \rho i \tag{8}$$

The total quantity of fish in the concentration is:

$$N = \sum_{i=1}^{i=n} Vi \rho i \tag{9}$$

To get the quantitative assessment of the school concentrations, the space between the search tracks is assumed to be equal to double the range of the sonar equipment. This searching pattern allows all the schools to be accounted for and plotted on the chart. The shape and vertical extension of schools are determined according to echo records for those schools which are encountered on the vessel courses. If a concentration is uniform and comprises fish of one species and of the same size and shape, the quantity of fish in the concentration is:

$$P_0 = n V_m \rho_m \tag{10}$$

where V_m = mean volume of school

n = number of schools

ρ_m = mean density of schools.

When the size of concentrations of the above type is estimated without sonar, the accuracy of assessment is in proportion to the number of tracks intersecting the concentration.

The quantity of fish in a concentration is found from the equation:

$$P_0 = \rho n V_m \frac{F}{f_e} \tag{11}$$

where F = concentration area

f_e = area sounded by echo sounder within the concentration outline.

The quantitative estimation of concentrations consisting of ten large sized schools of intricate shape spaced far from one another is done by summing up of the quantitative assessments of each of them. This refers to schools of herring, mackerel, khamsa and other fish. They extend sometimes for as long as a few miles.

The quantity of fish in a large sized school is found from the equation:

$$P_0 = \rho V \tag{4}$$

where V = volume of school.

To determine the volume of a school, it should be outlined and plotted on a panel of graph paper. The line of each track, through definite spaces, is marked with the vertical depth of the school in metres, then a system of isolines is drawn connecting the points of identical vertical extension. The computation is now reduced to determining the volume of the body confined by the surface known as a topographic one (fig 3).

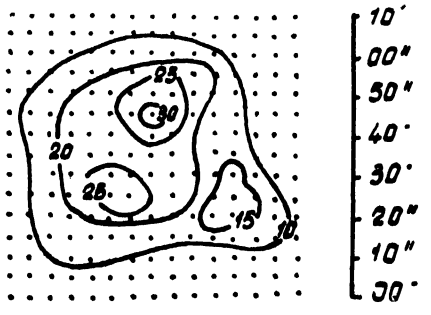

Fig 3. Scheme used to determine the volume of a school by a system of isolines on a transparent graph paper

QUALITATIVE ASSESSMENT OF COMMERCIAL CONCENTRATIONS

Qualitative assessment includes determination of fish size and species, behaviour of fish from a commercial catching standpoint, and forecasts of concentration stability.

The most important commercial behaviour characteristics investigated in commercial surveying are as follows: vertical migrations of fish and their pattern; fish response to noise emitted by vessels; fish response to fishing gear; fish response to electrical light.

The commercial behaviour of fish is investigated on a section of 10 to 20 sq mi where a few commercial schools are found or thinly concentrated fish are encountered. All the observations within that section are done continuously on the run of the vessel whose courses are so selected so as to perform a complete hydroacoustic survey of the assigned section (6 to 8 investigation periods a day) within three to four hours. One of the most important causes leading to vertical migrations of fish is a change in illumination during the day. If one is to forecast when the schools come up to the surface one should determine the normal light level at the depth of the school.

With other conditions equal, the illuminance is dependent on how high the sun is above the horizon. Therefore, it is necessary to study vertical migrations of fish by determining the depth of schools at different local times ($t1$):

$$t1 = t_m \lambda \frac{0}{W} \qquad (12)$$

where t_m = Greenwich (mean) time

λ = local longitude.

Figure 4 shows a graph of vertical distribution of herring during a day in a region of the Sea of Japan. The graph allows a determination of the mean velocity of vertical migrations of herring and the period good for purse seining.

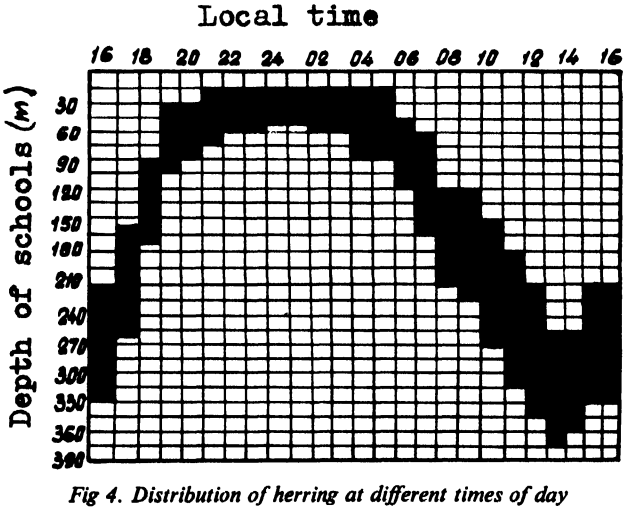

Fig 4. Distribution of herring at different times of day

While investigating the regularities in vertical migrations of fish it is also possible to detect their response to the illumination produced by underwater and surface light sources.

The response of fish to the vessel's propellers and engines is determined by changes in the school position when the vessel travels over the school at full speed, half speed and slow speed, and with the engines stopped. The observations are done with the aid of echo sounder and sonar. When the echo sounder records the centre of the school, a simple buoy is thrown into the water which can be easily seen at a distance of 1 to 2 mi; at night the buoy is lighted. The school's shifting aside is determined from the angle produced between the buoy and the school centre and by the distance to the school. When the vessel travels over the school centre for the second time it is possible to find out the depth to which the school goes down into the water due to the vessel passing over it.

It is important to find out how the fish respond to different sounds after they submerge in water. It is not infrequent that the fish school submerges to a depth of 10 to 20 m and ceases to respond to noise due to engine operation or to those produced by fishing gear; in this case the school can be successfully caught. Such behaviour of fish is often observed after they submerge. However, different species of fish and even different ages of fish may respond to noise in different manners. This means that the echo sounding recordings should be supplemented with test hauls.

The value of quantitative and qualitative estimations cannot be overestimated and improved methods for such estimations will mean higher efficiency in fishing.

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The Peruvian Eureka Programme of Rapid Acoustic Survey

by R. Villanueva

Prospection acoustique rapide à l'aide de navires de pêche

La technique de la prospection acoustique est désormais adoptée pour évaluer la distribution du poisson et indiquer l'abondance relative des stocks. Au Pérou, l'anchoveta occupe une zone halieutique d'environ 50,000 milles carrés. Une prospection acoustique, menée au moyen d'un seul navire, avec échantillonnage approprié, prendrait environ 30 jours. Durant cette période, la répartition des populations ichtyques varie constamment et une carte établie à partir de données d'une enquête non synoptique doit être fortement biaisée. En 1964, la flotte de pêche à l'anchoveta avait rencontré des difficultés pour déterminer les lieux de pêche hivernaux. L'Instituto del Mar del Perú a suggéré qu'une prospection conjointe soit entreprise à l'aide de navires de pêche, qui serviraient d'instruments d'enquête. Trois opérations navires à petite échelle ont été réalisée avec succès. Cette initiative a été reprise en 1966 et, depuis lors, 14 prospections analogues ont été effectuées, dont la moitié a suffit à courir la totalité de la côte. Les principaux problèmes ont été posés par la navigation, la répartition des navires et la normalisation du matériel acoustique. Une opération de prospection côtière utilise environ 20 seineurs commerciaux, suivant des routes parallèles, perpendiculairs à la côte. L'opération dure en tout une journée, et les renseignements obtenus pervent être communiqués à l'industrie 48 heures après la fin de la prospection. Outre les données acoustiques, on mesure les données suivantes: température des eaux de mer superficielles, bathythermographie, salinité et transparence de l'eau. Le coût de ces enquêtes est entièrement supporté par l'industrie. Une première tentative a été faite pour établir une relation entre l'écho-abondance, mesurée lors de ces opérations, et les prises par unité d'effort pour la flotille. Les résultats obtenus semblent encourageants et sont étudiés en détail.

Sondeos acústicos rápidos utilizando barcos pesqueros

Los sondeos acústicos son hoy día técnicas aceptadas para evaluar la distribución de los peces e indicar la abundancia relativa de los mismos. En el Perú, la anchoveta ocupa un área de pesca de unas 50 000 millas cuadradas. Un sondeo acústico de esa extensión con un solo barco, realizando un muestreo adecuado, requeriría hasta 30 días. En ese tiempo, la población de peces está sometida a cambios constantes en la distribución y, en consecuencia, el mapa de distribución de los peces que se obtiene a partir de los datos no sinópticos del estudio puede estar muy sesgado. En 1964, la flota pesquera de la anchoveta encontró dificultades para localizar los caladeros invernales. El Instituto del Mar del Perú sugirió una operación conjunta de investigación utilizando barcos pesqueros. Se realizaron tres sondeos a pequeña escala, que resultaron muy fructíferos. El programa se repitió en 1966 y desde entonces se han hecho 14 sondeos de ese tipo, la mitad de los cuales cubrieron toda la costa. Los principales problemas encontrados han sido la navegación, las averías de los barcos y la uniformación del equipo acústico. Para un reconocimiento de toda la línea costera se emplean approximadamente 20 barcos cerqueros comerciales, que siguen rutas paralelas normales a la costa. El reconocimiento se completa en un día y la información obtenida está en manos de la industria 48 horas después. Además de los datos acústicos, se mide la temperatura del agua en la superficie y a diversas profundidades (con el batitermógrafo), la salinidad y la transparencia de las aguas. Todos los costos de estos sondeos corren a cargo de la industria. Se ha hecho un primer intento de poner en relación la abundancia indicada mediante el sondeo acústico con las cifras de captura por unidad de esfuerzo de la flota. Los resultados parecen prometedores y se examinan en detalle.

FISHERY surveys, including acoustic observations, began in Peru in 1961. Early efforts were hampered by lack of experienced personnel, and poorly equipped vessels. But acoustic data gathered provided a basis for understanding anchoveta distribution and behaviour.

The major problem in designing an acoustic survey in Peru is the area of the anchoveta fishery. It encompasses virtually the entire coast from 50 to 80 mi seaward depending on the season, or an area of approximately 50,000 mi^2. With a single vessel, and a survey pattern which provides reasonable sampling density, the time required for a one-vessel survey is close to 30 days. During this period, the anchoveta population undergoes natural changes in density and displacements in distribution which are difficult to monitor. For this reason, concentrations of fish observed on one survey profile may be the same shoals that were observed on the preceding one. When the cruise data are analysed and isolines of anchoveta concentrations drawn between profiles, the resultant fish map can be very misleading.

Anchoveta behaviour differs greatly between day and night. During the day the fish are concentrated in schools; at night they are dispersed. This makes it impossible to use the same subjective criteria when evaluating abundance from day and night records. During the night it is also possible that many of the dispersed anchoveta remain very close to the surface, above the level of the transducer, and are lost to the acoustic record.

Considering these and other difficulties, it can be seen that a serious bias must exist in estimations of both abundance and distribution from these one-vessel surveys. What is needed, therefore, is the fishery to be surveyed rapidly to reduce the effects of fish movements and behaviour changes.

In 1964, the Peruvian anchoveta fleet was having difficulty finding the winter fishing grounds, and the staff of the Instituto del Mar del Peru was unable to provide the fleet with an answer. In view of their reciprocal interests, a joint programme was arranged using commercial vessels for rapid survey work. After three successful explorations this programme called QUIZAS (the Spanish word for Perhaps) was discontinued, but a foundation was laid for future collaboration. The programme was revived in 1966. Since then 14 surveys have been made, many of which covered the entire fishery area. The survey area is covered completely within a 24-h period, and most of it during daylight hours.

The new programme has been named EUREKA (I have found it!). Table 1 shows dates, number of vessels and final report numbers for all surveys to date. These reports are unpublished, but are available on request from the Instituto del Mar. The surveys are usually made during the closed seasons because vessel time is relatively inexpensive as there is no conflict with fishing.

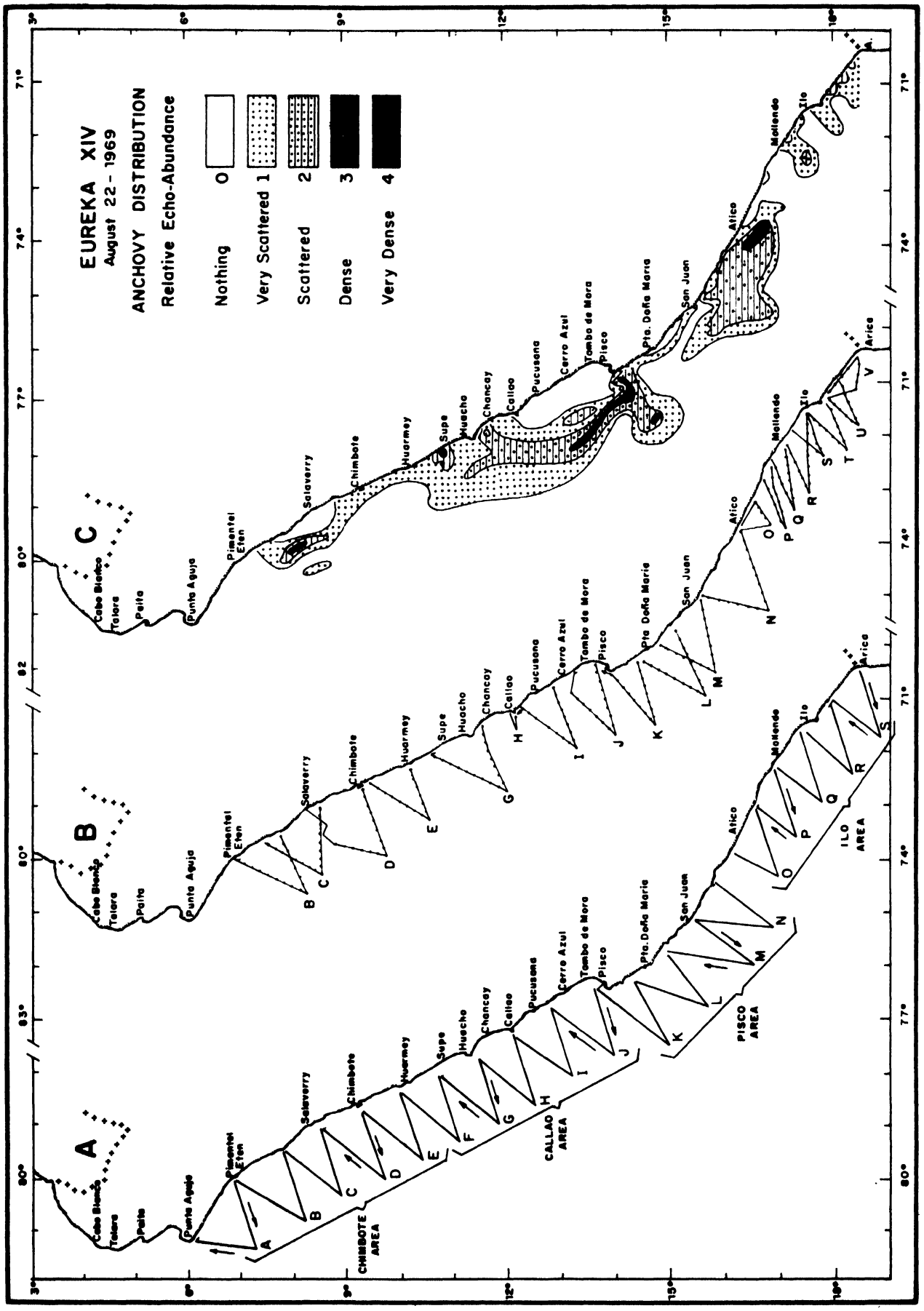

Fig 1. The Eureka XIV survey along the Peruvian coast (22 August, 1969)
A = proposed cruise tracks; letters designate individual vessels; braces designate zones. B = plotted tracks from ship logs. C = resulting fish map of anchoveta abundance and distribution

TABLE 1. RAPID ECHO SURVEYS MADE SINCE 1964

Cruise	*Date*	*No. of boats*	*Report no.*
Quizas I	22 June 1964	10	COM-2
Quizas II	18 July 1964	10	COM-6
Quizas III	3 September 1964	15	COM-7
Eureka I	6 February 1966	7	IMP-6
Eureka II	13 February 1966	5	IMP-6
Eureka III	16 April 1966	6	IMP-7
Eureka IV	23 April 1966	7	IMP-7
Eureka V	5 July 1966	6	IMP-8
Eureka VI	6 August 1966	6	IMP-10
Eureka VII	10 March 1967	8	IMP-13
Eureka VIII	24 August 1967	16	IMP-14
Eureka IX	12 March 1968	15	IMP-25
Eureka X	23 August 1968	10	IMP-29
Eureka XI	22 February 1969	6	ILO-1
Eureka XII	24 May 1969	6	ILO-2
Eureka XIII	21 July 1969	21	IMP-50
Eureka XIV	22 August 1969	20	IMP-50

The information gathered at these times, also, is more valuable to the fleet, as it provides a basis for predicting locations of fish concentrations prior to the opening of fishing.

The Instituto de Fomento Pesquero de Chile has a similar programme called NORTE (North). During 1969, four joint cruises were made in the southern Peru/northern Chile area. This exchange of information will assist in the study of population fluctuations in the southern extreme of the fishery.

Eureka survey coordinated with industry

Once a survey has been decided on, a meeting is called with representatives of the industry. The participants are usually managers of fishing companies. During these meetings, routines of work, number of vessels needed, dates, and times are established. Staff of the Instituto are designated as regional cruise leaders, and keep in contact with fishery operations managers concerning any changes in plan, and final preparations.

The entire cost of the survey is borne by the industry. For a recent 20-vessel survey, the cost was approximately US$5,000. This included travel expenses, vessel logistics, crew wages and material.

Vessels and equipment

The vessels used are standard anchoveta purse seiners—all equipped with echo sounders. In most recent surveys, all have been equipped with sonars also. An attempt is made to use boats with identical types of acoustic equipment, but this is not always possible. The sounders are calibrated crudely by setting the gain to record a weak third bottom echo at 50 m depth. They are operated on the highest paper speed and the shallowest depth scale available on the particular set. The sonars are programmed to search side-to-bow automatically, on maximum ranges, and full output power. In addition to the electronic equipment, each boat is equipped with a bucket thermometer, and a Secchi disk. Every fourth vessel has a bathythermograph on board. Their radios are equipped with two private frequencies, and they can communicate with the other vessels, as well as with fishmeal factories along the coast. A representative of the Instituto del Mar is aboard each vessel, along with approximately six crewmen.

Survey design

The projected cruise plan for Eureka XIV is shown in fig 1(a). Letters designate individual vessels. Starting points are placed at regular intervals along the coast, and tracks are designed to be as parallel between vessels, and as normal to the coast as possible. For this survey, the seaward leg extended 80 mi from the coast. The starting points are within visual distance of prominent coastal features that are known to the fishing captains. This is necessary because there are no navigation aids in Peru, and only the most basic dead-reckoning is practised.

Boats leave home ports so as to be on station early on the morning of the survey. For some this may mean as much as 24 h of running time. At 0600 h the vessels leave on their designated courses. Stations are taken at the starting point, and each hour of running along the course. At the end of the seaward profile, the vessels turn and run to the coast. The end point of this track is designed to be the beginning point of the next boat to the north. The point of actual landfall is carefully ascertained from local coastal features.

Data collection

Figure 2 shows the data form used on surveys. Much information is uniformly coded to expedite analysis. The columns are arranged for station data; some information pertains to running time between stations, such as acoustic data, course and speed. The latter entries are collected between the present station and the previous one, or during the past 60 min of running. This means two entries in the acoustic columns, as the records are analysed each 30 min. Non-acoustic information is recorded to establish environmental conditions of fishery during survey.

Salinity samples are not taken at each station, but each vessel normally takes at least three samples at designated points along its track. Biological samples are taken only at the special request of the Institute, and these consist of standard net hauls.

Analysis of data

First priority is to establish tracks covered by the vessels. Starting and ending points as well as changes in course and speed are taken from the vessel logs and plotted. Figure 1(b) shows the plotted tracks, which can be compared to the proposed tracks in fig 1(a). The lack of any navigation facilities in the fleet will always be a problem. Inherent errors between plotted and actual tracks, however, are considered to be within the scope of survey accuracy, considering the subjective nature of the fish map which is developed from the survey data.

At times, vessels develop trouble, drop out and return to their home ports (vessel H and O). Other vessels have early problems, and do not even start the survey (vessels A and F). These problems often involve malfunctions of the acoustic equipment.

Preliminary analysis of acoustic data is begun while vessels are at sea. Technicians on board the vessels analyse the echo-sounder traces each half hour, and radio this information to their regional cruise leader. These data are then relayed to the shore stations, where

STATION DATA SHEET FOR RAPID ECHO-SURVEYS

EUREKA Nº_____ DATE _____ PROFILE-AREA _____ VESSEL _____ SHEET Nº___

STATION NUMBER						
HOUR: START/FINISH						
COURSE / BOTTOM DEPTH (m)						
R.P.M./SPEED (KNOTS)						
SURFACE TEMPERATURE (°C)						
QUANTITY OF ECHO-TRACES (I)						
TOP OF SCHOOL (m)						
TYPE OF ECHO-TRACE (II)						
SECCHI DEPTH (m)/COLOUR (III)						
SEA: STATE*/DIRECTION						
WIND: STATE*/DIRECTION						
SKY (IV)						
FISH ON SURFACE (V)						
BIRDS ACTIVITY (VI)						
Nº OF BOATS FISHING						
BIOLOGICAL SAMPLES (VII)						
B.T. DEPTH (m)						
SALINITY SAMPLES Nº						
OTHER OBSERVATION						

CODE

I	II	III	IV	V	VI	VII
0 Nothing	Pl. Plumes	pa Grayish	D Clear	a Anchovy	c Eating	Ft. Phytoplancton
1 Very Scattered	M Spots	ve Green	Cp Partially Cloudy	b Tunnidae	v Flying	Zoo. Zooplancton
2 Scattered	CM Mixed Layers	v Greenish	C Cloudy	pv Flying Fish	r Resting	An. Anchovy
3 Dense	C Scattering Layers	av Blue green	N Mist	t Sharks		Ot. Other
4 Very Dense	T Individuals Traces	am Deep blue		d Porpoises		
				c Whales		

* BEAUFORT SCALE

Comments:

Fig 2. Standard data sheet for Eureka surveys

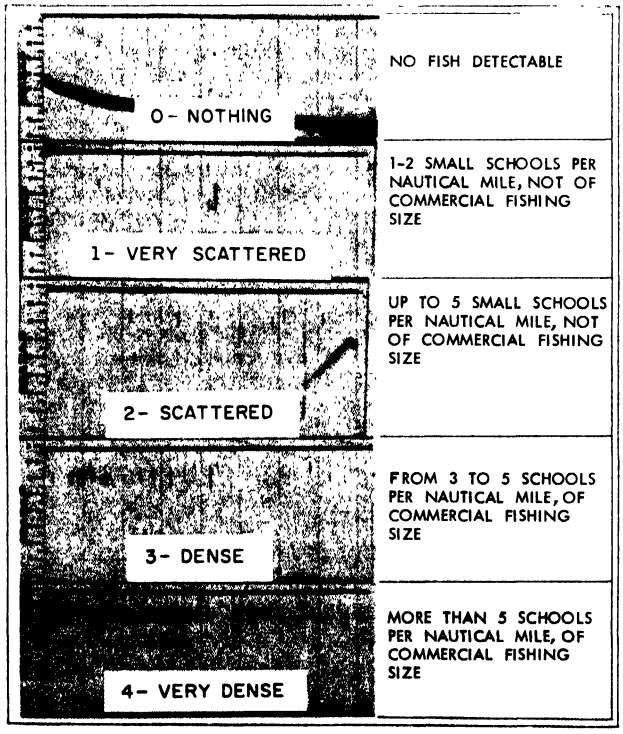

Fig 3. Quantitative scale used for acoustic record analysis. Vertical lines are nautical miles; depth scale is in fathoms (brazas)

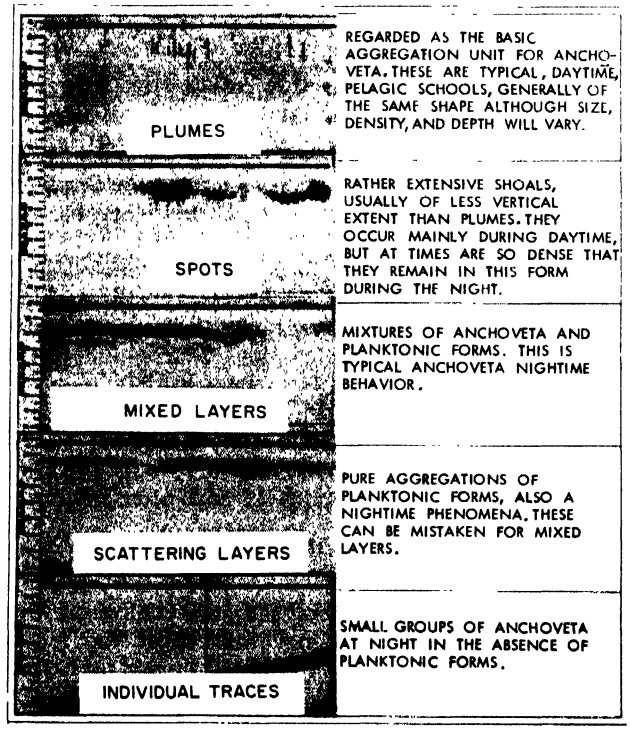

Fig 4. Typical traces associated with Peruvian anchoveta. Depth scale is in fathoms (brazas)

a preliminary fish map is being prepared. The quantitative scale of relative abundance levels used for record analysis is shown in fig 3. This scale is based on anchoveta schools per nautical mile. A similar scale was used by Vestnes and Saetersdal (1964) for their anchoveta exploration work in Chile. Depending on time of day, season, and geographical location of the observations, different types of traces associated with anchoveta occur and are described in fig 4. These qualitative descriptions have been based on the work of Cushing (1957), but modified to better describe local conditions.

At times, other pelagic schooling species such as jack mackerel or squid are present. An experienced observer, however, usually can distinguish these and delete them from the anchoveta map. At any rate, the size of all these populations compared to that of the anchoveta is very small, and the resultant error will be negligible.

At the end of the survey when the echo records reach the Instituto, the field analysis is checked, and the fish map is revised. Sonar records are analysed by counting schools per nautical miles and this provides supplementary data. The completed fish map for Eureka XIV is shown in fig 1(c). It has been made by contouring the relative abundance levels.

Report and distribution

The final report is ready for distribution 48 to 72 h after the survey ends. This report consists generally of seven charts:

1. Vessel tracks and station positions.
2. Surface temperature distribution (by 1°C).
3. Surface salinity distribution (by 0.1‰).
4. Fish map showing distribution and concentrations (as fig 1(c).
5. Zones of major availability.
6. Vertical temperature and anchoveta distribution profiles along tracks of bathythermograph-equipped vessels.
7. Secchi disk extinction value (by 5 m depth increments).

The Secchi disk extinction chart is included because water clarity is of great importance to the fishing fleet in a tactical sense. The best fishing occurs when the water is most opaque.

Along with the charts is a commentary which describes relationships between the anchoveta and the ambiental conditions. Also included are tables showing mean school depth and extent by zones, and course and distance from major ports to areas of high availability. If two cruises are made within the same closed season, a discussion of changes in ambiental conditions and fish distribution is included. This was the case for the Eureka XIV report, since Eureka XIII had been run just 30 days before.

Benefits gained

The benefits of this type of survey are obvious. For a small expenditure in money and effort the industry receives quality intelligence on anchoveta availability. This is especially useful when the survey is carried out shortly before the opening of a fishing season.

For long-term studies this information is very useful to the Instituto del Mar. As more survey data of this type is gathered, seasonal and yearly changes in abundance, distribution, and relationship to ambiental condition can be observed. From these observations, forecasting tools may evolve which will increase harvesting efficiency and assist in fishery regulation.

As an example, an echo-abundance index has been devised which can be extracted from the fish map. A similar index has been described by Burd (1959). The map has been made by contouring fish abundance levels as described in fig 3. The areas within each level are found with a planimeter, and these are then multiplied by numerical values of the corresponding levels of fish abundance. The sum of the resultant figures divided by the total search area is the echo-abundance index. When this index is plotted against fleet catch-per-unit-effort values for the month following the survey, a definite trend is observed (fig 5). Only those cruises from 1966 through

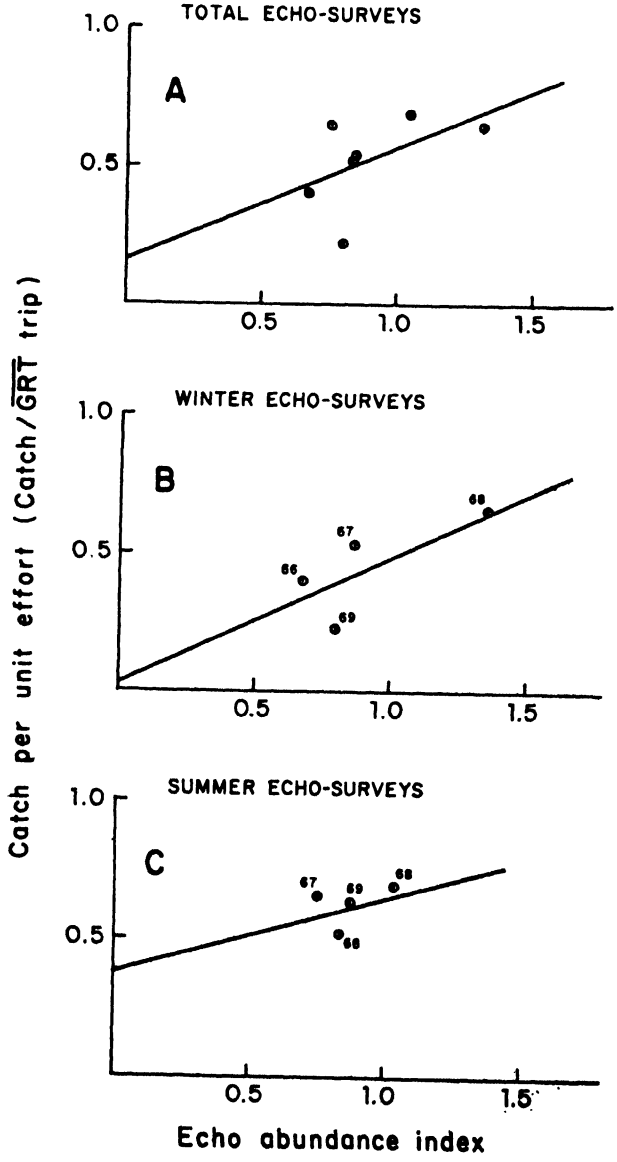

Fig 5. Survey echo-abundance index versus catch-per-unit-effor data for the month following the survey. Data from 1966 through 196 A = all surveys; B = winter surveys; C = summer surveys

1969 were used because they were coastwide, and both summer and winter data were available. The difference in the slopes of the lines between summer and winter cruises is due to higher, summer catch-per-unit-effort figures. During the summer, the anchoveta are concentrated near the coast, and are more available to the fleet. More data is needed to confirm these trends, but it can be seen that this could be a future tool for predicting anchoveta availability, and for studying exploitation levels.

Many problems inherent in these surveys are difficult to overcome. Possibly the most serious is inaccurate navigation; this will remain so until some electronic navigation facilities are available. Some breakdown of vessels and acoustic equipment is inevitable, but a more stringent control could be exercised by assigning a standby vessel for each region. Discussions with industry on these points have been progressing.

Future plans for these surveys include the possible addition of high-speed plankton samplers for rapid census of eggs and larvae. In addition, if standby vessels could be assigned, and were not needed, they could be used to sample high concentration of adult fish with their purse seines to obtain values of absolute school density. Such data would be valuable for quantitative assessment.

Acknowledgements

The author acknowledges with gratitude the assistance of Mr. I. E. Davies (FAO), of Mr. V. Valdez, who first conceived this type of survey, and Mr. A. C. Burd, who helped Eureka gain acceptance as a regular programme, and finally, of Dr. J. Sanchez, Technical Director of the Instituto del Mar, who coordinated these surveys with industry, and made them possible.

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Temperature Telemetry as an Aid to Fish Finding

by H. von Seydlitz

La télémesure de la température-aide à la recherche du poisson

La température de l'eau est considérée comme un des principaux facteurs du milieu qui influencent la répartition et l'abondance du poisson et des corrélations ont été établies respectivement pour un certain nombre d'espèces commerciales. Parce qu'elle est relativement facile à mesurer, elle peut être également utilisée comme indicateur de la présence du poisson par les pêcheries commerciales. On décrit un équipement de thermo-netsonde récemment mis au point qui permit, en combinaison avec le sondage du netsonde et au moyen d'un câble reliant le chalut au chalutier, d'observer d'une manière continue la température de l'eau à l'entrée du chalut pendant la pêche. Un certain nombre d'exemples sont donnés pour montrer les bénéfices obtenus au moyen de cette technique par l'amélioration de l'efficacité du chalutage du hareng, de la morue et du merlu. On espère que l'utilité de cette technique augmentera considérablement avec une expérience plus étendue et que, de cette façon, la télémesure de la température pourra constituer éventuellement une aide normale pour le chalutage pélagique et aussi pour le chalutage de fond.

Empleo de la termotelemetria para la localización de peces

La temperatura de las aguas es uno de los principales factores ambientales que influyen en la distribución y abundancia de los peces, y se han establecido las correspondientes correlaciones para diversas especies comerciales. Como se trata de un factor relativamente fácil de medir, incluso las pesquerías comerciales pueden emplearlo como índice de las disponibilidades de peces. Se describe un nuevo equipo de termosonda instalado en la red, que, combinado con un equipo de sondeo acústico también montado en la red, permite, por medio de un cable que pone en comunicación la red de arrastre con la embarcación, observar continuamente durante la pesca la temperatura del agua en la red de arrastre. Se citan varios ejemplos que muestran los beneficios que es posible obtener con esta técnica en el aumento del rendimiento de la pesca de arenque, bacalao y merluza al arrastre. Se espera que la eficacia de esta técnica aumente notablemente a medida que se consiga mayor experiencia, de modo que la termotelemetría podría llegar a convertirse en un instrumento normal para la pesca al arrastre entre dos aguas y también en el fondo.

IN modern oceanography the attempt to correlate environmental conditions to the distribution and abundance of fish is becoming increasingly important. This correlation, which is also of significance regarding the productivity of fish stocks and the understanding of their migrations, is not only of interest for biological studies but also for rational fish location in commercial fishing.

In a review paper (Dietrich, Sahrhage and Schubert, 1959) the authors came to the following conclusion:

> ". . . Among the different factors of ecological systems . . . temperature and food are the most outstanding. . . . Therefore the temperature may be used as the most practicable indicator of ecological conditions".

This conclusion is supported by Hela and Laevastu (1961) who also list characteristic temperature ranges for

a number of fish species in different areas. Apart from the distribution of fish species in general, for commercial fishing the relation of stronger concentrations to certain temperature ranges is of particular interest.

The temperature preference of a certain fish species is often not constant but may change during a yearly cycle in connection with the physiological situation such as spawning or feeding. During the relevant migrations the fish may have to pass through different environmental conditions. This change of temperature preference must be taken into account when using temperature measurements for fish location. Since the water temperature often varies considerably with depth, the temperature at the fishing gear must be determined for fishing purposes. Until recently reversing thermometer or bathythermograph have been the only means for temperature measurement in greater depth. While these instruments are satisfactory for scientific investigations they are inconvenient for commercial trawling because they allow only spot measurements. In areas with convergences like the Polar Front, where cold polar water meets warmer water from temperate latitudes, the water temperature in the working range of a trawl can change considerably during one tow. This can lead to the waste of fishing time in unsuitable water bodies and it is therefore desirable to continuously observe the water temperature during towing.

Instrumentation

In the German trawl fishery the echo sounding netsonde has become standard equipment for midwater trawling and is also being used increasingly in bottom trawling. A cable connection of this netsonde between the trawl and the trawler is now being utilized, also for the transmission of temperature measurements at the headline of the trawl. The German industry has developed two different types of "thermosonde" which can be attached to existing netsonde equipment, without major changes (fig 1). In one type the thermosensor is included in the transducer board, while in the other the thermometer device is contained in a separate spherical container of trawl float size, which is attached close to the transducer board at the headline and connected to the netsonde cable inductively by a ferrite bobbin. The temperature measurements are either indicated by a separate display or appear as an additional dotted line on the echo recorder paper (fig 2) (e.g. Grossheim, 1969).

Application of thermo-netsonde in trawling

The new equipment was installed in 1969 in a number of German long-distance trawlers and tested during commercial fishing, also by the Institut für Fangtechnik, on herring and cod on some major fishing grounds.

During July 1969 in the Gulf of Maine the best herring concentrations were found in water of 7.0° to 7.9°C (44.6° to 46.2°F). Below 7°C (44.6°F) and above 8°C (46.4°F) the average catches dropped to less than 50 per cent. Below 6°C (42.8°F) no herring was found at all. Since at this time the location of herring off the American coast was quite problematic the temperature observations provided a distinct advantage.

In the Irish Sea during September 1969 the best herring catches were also obtained in water of 7° to 8°C

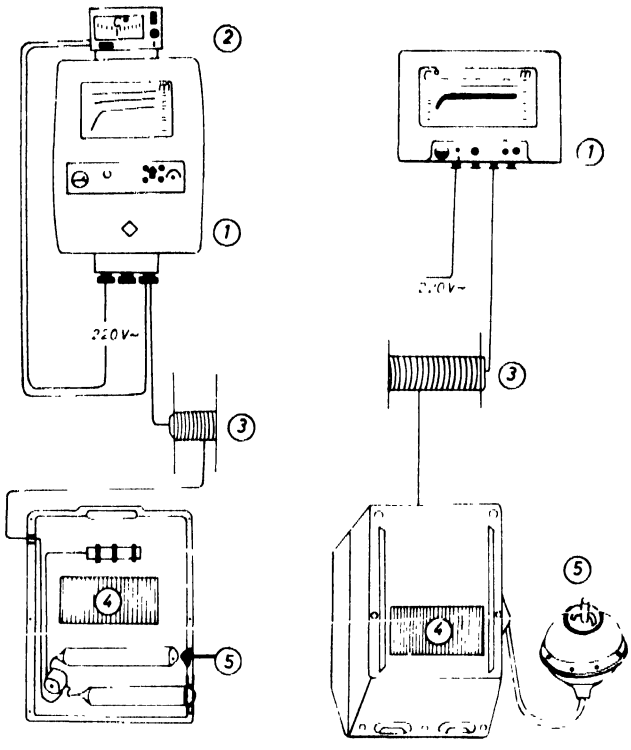

Fig 1. Schematic view of the combination thermo-netsonde
1. *First system: Recorder unit of netsonde with additional temperature recording.*
2. *Second system: The indicating instrument for the temperature is fixed to the echo recorder*
3. *Winch for netsonde cable*
4. *Echo transducer in netsonde transducer board which is attached to the headline of the trawl*
5. *Thermosensor*

Fig 2. Netsonde echogram taken during midwater trawling for cod off Greenland in December 1968 with temperature recording (Grossheim, 1969). Extreme top line shows headline, next, footrope, "milled" line shows temperature and dark mass the seabed

(44.6° to 46.4°F). In warmer water up to 11.9°C (53.4°F) herring was much less abundant and was partly replaced by the unwanted mackerel and horsemackerel (fig 3). Midwater trawling was mainly at night. By means of the thermo-netsonde, it could be observed that the herring did not ascend into the upper layers of warmer water, so that midwater trawling had to be conducted below the thermocline and close to the bottom (fig 4).

Herring trawling on the spawning grounds near the French coasts in December 1969 was particularly success-

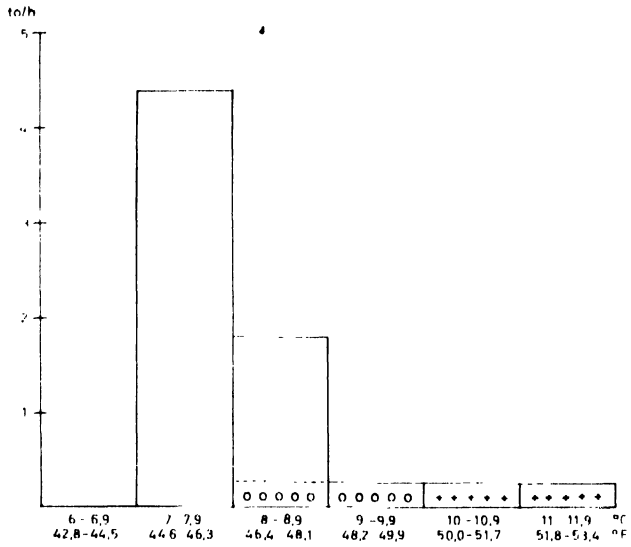

Fig 3. Average catches per hour of a German midwater trawler in the Irish Sea (13th to 18th September 1969) in relation to water temperature at the net. Plain white = herring; ○ = mackerel; + = horse-mackerel.

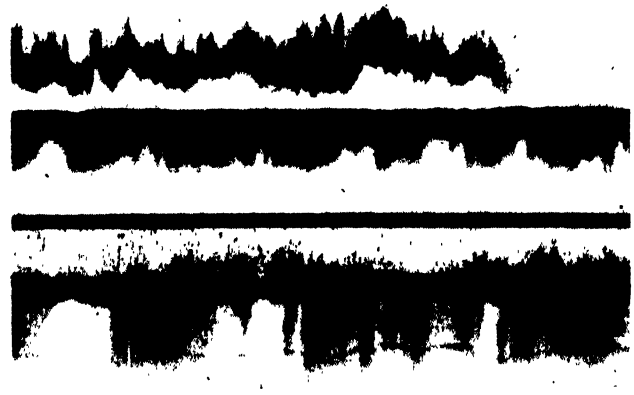

Fig 4. Ship's sounder (above) and netsonde (below) echograms of midwater trawling for herring in the Irish Sea (19th September 1969, 2300 h). As shown in Fig 3, herring kept in lower water layers of 7 to 8° C (44.6 to 46.7°F) so that the midwater trawl was towed with the footrope very close to the bottom.

ful at water temperatures between 10.5° and 11°C (50.9° and 51°F).

In Greenland waters the cod migrates between the cold water of the feeding areas to warmer water of the spawning areas. During December 1968, successful midwater trawling for cod was conducted in water layers with a temperature between 3° and 4°C (37.4° to 39.2°F). It was most advantageous to tow the headline of the midwater trawl by help of the thermo-netsonde in 4°C (39.2°F) (Grossheim, 1969).

During March 1969 concentrations of mature prespawning cod were found off Greenland, again in water of 3° to 4°C (37.4° to 39.2°F). Here skippers could improve also the bottom trawling efficiency, using temperature observations to determine optimum trawling time and trawling course. The average catches diminished with decreasing temperature and became uneconomic below 2°C (35.6°F).

In hake trawling off the South African coast it was observed that good catches were related with a water temperature range between 6.5° and 7.9°C (43.7° and 46.2°F). This was confirmed by trawling experiments in 1967 (v. Brandt, 1967), during which the best average catches were obtained at water temperatures between 7.5° to 7.9°C (45.5° to 46.2°F).

CONCLUSIONS

Although scientific and fishing experience is still limited, it is generally agreed that the water temperature in many instances can serve as an indicator for fish distribution and abundance. With equipment such as the thermo-netsonde advantage can be taken of this correlation to improve trawling efficiency. It is to be expected that increased application of such instruments in experimental and commercial trawling will significantly further the knowledge of the correlation between water temperature and fish distribution, so that temperature telemetry during trawling in combination with netsonde sounding may eventually develop into a standard technique.

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Application of Oceanographic and Meteorological Analyses/Forecasts in Fisheries

by T. Laevastu and J. Johnson

Application des analyses/prévisions océanographiques et météorologiques pour la pêche

Certains paramètres de milieu, en particulier la température, peuvent être utilisés pour déterminer les zones où des espèces déterminées peuvent être presentées en concentrations exploitables. Les anomalies de température de la mer sont particulièrement intéressantes dans les zones proches des limites de distribution d'espèces données pour déterminer les retards de fraie et les déplacements des terrains de fraie. En raison des effets du milieu sur la détection du poisson au sonar, le recours aux observations synoptiques BT et XBT prend davantage d'importance pour l'utilisation du sonar ainsi que les opérations de pêche. Il est maintenant possible de prévoir les courants (y compris les courants de marée) avec une précision relativement grande. Ces prévisions deviennent de plus en plus importantes pour améliorer les opérations de pêche, notamment au chalut et à la senne. Les prévisions météorologiques à moyen termes améliorent lentement et sont utiles pour l'organisation des pêches et le calcul des routes des navires. Il est posé en postulat qu'on dispose déjà d'une masse suffisante d'informations sur le comportement des poissons en liaison avec les facteurs de milieu, masse qui peut être utilisée avec les analyses/prévisions océanographiques synoptiques en vue de réduire le temps de recherche et d'améliorer les tactiques de pêche. Il est nécessaire de diffuser ces informations parmi les pêcheurs.

Aplicación a la pesca de los analisis y las previsiones oceanograficas y meteorologicas

Varios parámetros ambientales, especialmente la temperatura, pueden servir para determinar las zonas en que es posible encontrar determinadas especies en cantidades pescables. Las anomalías de la temperatura de las aquas son especialmente útiles en las zonas próximas a los límites de distribución de ciertas especies, para determinar los retrasos de la freza y el desplazamiento de los peces en busca de frezaderos. Dados los efectos del ambiente en la localización de los peces mediante sonar, el empleo de observaciones sinópticas con batitermógrafos normales o expansibles está adquiriendo cada vez mayor importancia para la localización de los peces con sonar y para las operaciones de pesca. Actualmente es posible predecir las corrientes (incluidas las motivadas por las mareas) con precisión relativament grande. Esta información reviste cada vez mayor importancia para mejorar operaciones de pesca, como las de arrastre y cerco. Las previsiones meteorológicas a plazo medio van mejorando paulatinamente y son útiles para planificar la pesca y fijar la derrota de los barcos. Se sostiene que existe ya información suficiente sobre los movimientos de los peces en relación con los factores ambientales y que esa información puede emplearse, junto con los análisis y las previsiones oceanográficas sinópticas, para reducir el tiempo de exploración y mejorar las tácticas de pesca. Es necesario divulgar esa información, haciéndola llegar a los pescadores.

IN general, fishery scientists have failed to translate results of their research into practical applications for the benefit of the fishing trade, especially for the fisherman at sea. In the past, a high percentage of fisheries research has been carried out as basic research. Results of this research have been published in the vocabulary of the scientist. When not much was known of life histories of various species, their environmental requirements and their behaviour, this approach was acceptable. Now, however, a vast reservoir of data and knowledge is available on these subjects. Fishery scientists should now spend as much time in applying results of past research for the economic benefit of fisheries as in searching for new knowledge.

In some quarters, public support for fisheries programmes is rapidly dwindling. One simple reason is that the general public and the fishing industry are not seeing enough tangible benefit for the money and manpower spent over the last several decades in fishery programmes. Some fisheries in severe economic crises could be assisted by scientists if research programmes would be reoriented for more direct benefit of the industry.

It should be mentioned that past fisheries research has in many cases been oriented to answering questions and creating a basis for fisheries regulations and resource conservation. Many of the latter have not been successful and have created animosity among fishermen towards fisheries research. It is thus time for appeasement by showing that fisheries authorities are also able to provide services to fisheries that will increase their efficiency.

An attempt is made in this paper to show by a few examples how the gap between research and application might be bridged.

Readers are referred for additional details as well as for references to a book entitled *Fisheries Oceanography*, by Hela and Laevastu, Fishing News (Books) Ltd., London, recently published.

ENVIRONMENTAL ANALYSES/FORECASTS IN FISHERIES

Of a multitude of possible applications where knowledge of effects of environmental conditions in the fisheries might result in economic benefit to the fisheries, only a few can be presented here. In this paper, the term environment implies the physical conditions in the sea and in the atmosphere.

Scientists usually seek answers to biologically oriented questions, e.g. a given fish species reaches maturity at 2 years of age and is then an average 15 cm long—how can I apply this knowledge to fisheries? The application of findings of this nature relate mostly to management of fisheries. The industry, in our case the fisherman, seeks the answers to questions of a different nature, e.g. how can I determine from environmental parameters, such as temperature (which is easy to measure), where the most profitable concentrations of fish are located at a given time and region. Furthermore, he asks if weather conditions will permit fishing these stocks. We follow the inquiring philosophy of the fisherman in this paper.

Fish location

If there are meaningful relations between the occurrence of fishable concentrations of fish and some easily observed environmental parameters, it would be possible to

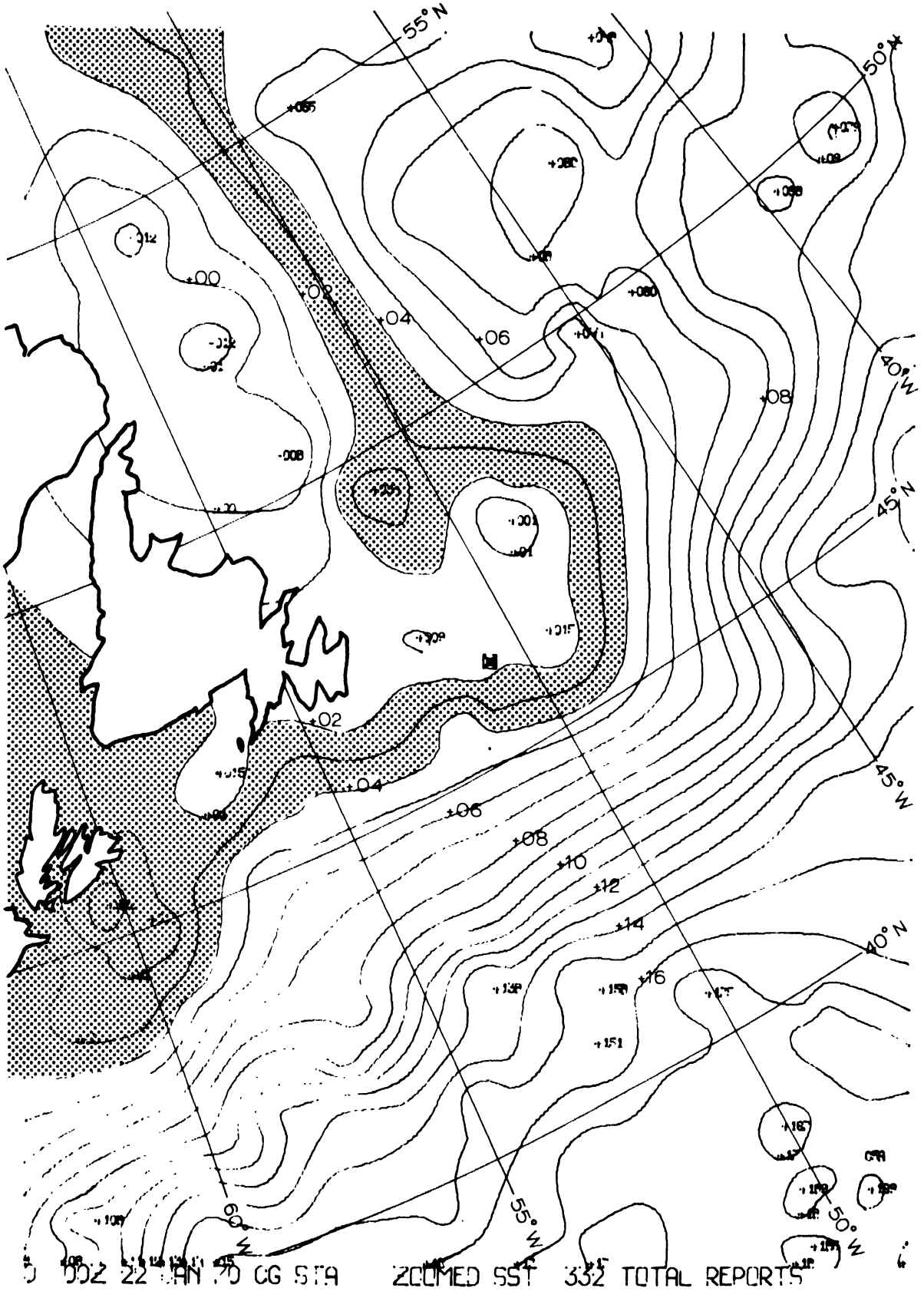

Fig 1. Sea surface temperature analyses off Newfoundland–Grand Banks area on 22 January 1970 (the areas with temperatures 2 to 4°C are hatched as hypothetical examples)

delineate the areas of search for fish from environmental analyses/forecasts, thus cutting wasteful scouting time. For many commercial fish species such meaningful relations have been found. For example, optimum temperature range for the cod is 2° to 3°C during the winter and 3° to 5.5°C during the summer. Thus, if synoptic sea temperature analysis charts are available, the general areas for possible occurrence of cod can be delineated, especially during the winter, when the sea is isothermal from surface to bottom over many continental shelves and shallow seas. A hypothetical example of this is shown in fig 1. After the general area of profitable fishing has been outlined through use of temperature criteria, further definition can be achieved by applying other knowledge such as depth of the water, type of bottom preferred by fish, trawlability of the bottom and the historically known (or traditional) fishing grounds.

The above information alone might not be sufficient in many instances and other factors such as temperature anomalies and their persistency must be investigated. One such example is schematically shown in fig 2.

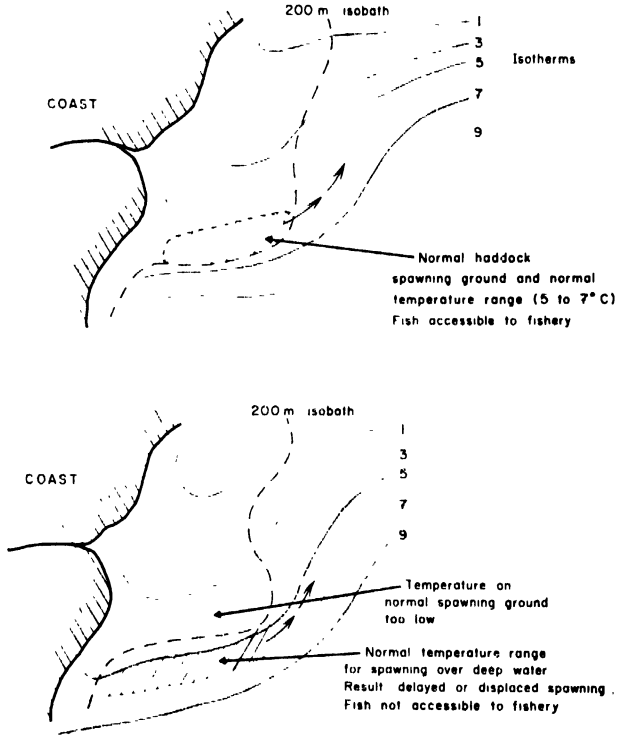

Fig 2. Schematic example of the effect of negative temperature anomaly on haddock spawning and fishing

Haddock spawn in April at the continental slope within a temperature range of 5° to 7°C (upper figure). In a given year, temperature conditions on the normal spawning ground may be too cold for spawning (lower part of the figure). Thus, good fishable concentrations of haddock would not be expected here. The spawning areas might have been displaced horizontally or the fish might spawn in deeper layers and not be accessible to fishing. Furthermore, there may be a delay of spawning activity, especially if there was a large-scale negative temperature anomaly in the general area (which we can ascertain from past synoptic analyses and anomaly computations); thus, a late season for the fishery may be expected.

Having ascertained (or selected) one or several general areas for fish search from synoptic analyses of sea surface temperature (SST), one has to look thereafter at the vertical temperature structure analyses/forecast, which includes mixed layer depth (MLD) forecast. For our hypothetical example assume that cod in a given region normally spawn at temperatures between 3° and 5°C. In a given year the temperature at the spawning time and ground may be 2°C warmer. This might force the fish to spawn in deeper water where the stock may not be accessible to the usual fishing gear. This would dictate the use of different gear (e.g. longlines at the bottom instead of trawling).

An example of the possible effect of MLD on purse seining—in the case of a deep MLD the schools might dive out from the seine, if the netting does not reach through the MLD. If the MLD is shallow and the thermocline gradient sharp, the sudden diving of schools through a "temperature barrier" is less likely.

Finally, it should be emphasized that vertical ocean thermal structure can have a pronounced effect on fish location with sonar.

Fishing operations

Having determined the possible area for fish location and/or fishing from environmental analyses/forecasts, the fisherman must ascertain and verify the conditions on the fishing ground with direct observation. If he finds the conditions do not correspond to forecast, the analyses/forecast charts will usually tell him in which direction to move.

The use of synoptic BT (bathythermograph) and XBT (expendable BT) observations by fishermen is rapidly increasing. Two characteristic XBT traces are shown in fig 3. Many fishermen learn to use the XBT for their own benefits rapidly as is evident from two examples of our experiences at FNWC (Fleet Numerical Weather Central, Monterey, California). By digitizing XBT traces from an Icelandic trawler we found that with certain thermal structures the positions of XBT observations changed rapidly, i.e. the vessel was underway or searching for fish. With other very characteristic temperature profiles, the XBT positions changed very little and the ship had a tendency to take more XBT casts, i.e. the vessel was fishing. From the study of XBT traces it appeared that the vessel found good cod or redfish fishing on the continental slope of Greenland where there was a pocket of warm Atlantic water below cold East Greenland water in a certain depth interval.

The other example is from tuna fishing in the Eastern Central Pacific. A tuna purse seine vessel was always underway when MLD was deep, but moved little in areas where MLD was shallow. Apparently, fishing success was best in areas of shallow MLD.

Another schematic example of the possible effect of MLD on midwater trawling indicates the need for synoptic BT observation by fishermen, not only for fish location but also for fishing tactics—e.g. for the depth control of a midwater trawl in relation to thermal structure. This fishing tactic takes advantage of the

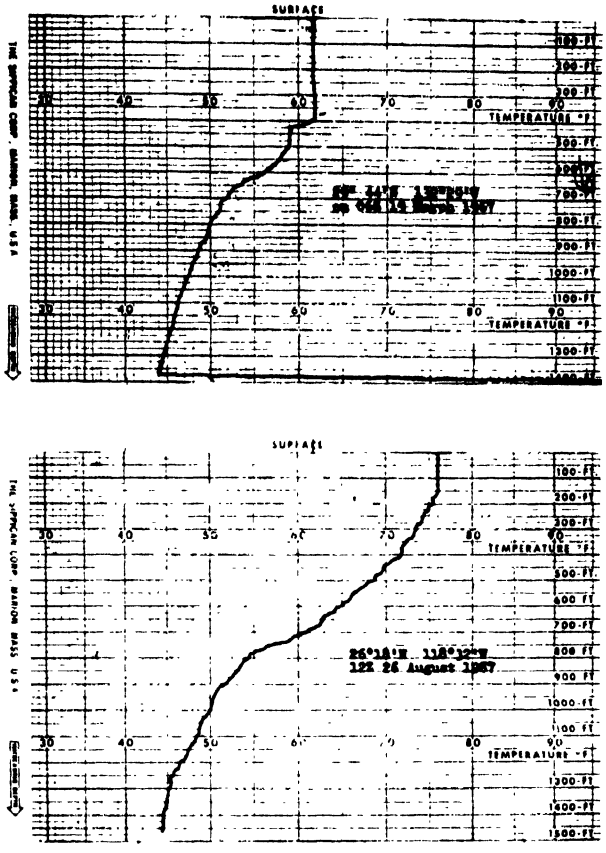

Fig 3. Two characteristic XBT traces

knowledge that many fish do not easily penetrate sharp thermoclines. These act as barriers and thus serve as an aggregating mechanism.

It has been demonstrated lately (and has been known to a number of fishermen earlier) that the synoptic knowledge of stronger tidal currents is of considerable benefit in trawling and seining operations. This knowledge is needed especially if the (tidal) current direction is considerably different from the direction of the wind and the sea. Having this information, the fisherman can then modify his fishing tactics accordingly, in setting the seine and/or trawling direction as well as for proper control of the midwater trawl. Furthermore, some, if not most fish orient to stronger currents in some situations, and show different schooling behaviour in different strengths of tidal currents.

The synoptic picture of currents has not been available in the past, mainly due to observational difficulties. However, the currents, especially tidal currents, can now be predicted with relatively high accuracy and with considerable amount of detail, using large electronic computers and Hydrodynamical Numerical models (see fig 4).

Knowledge of prevailing thermal structure is in certain conditions useful in acoustic control of trawls and in keeping track of schools in seining operations. For example, a vessel might lose a school on the sonar scope at the start of seining operations which might be due to short ranges caused by an unfavourable thermal structure.

Relatively little use has been made of the knowledge of the environment in the past mainly due to non-existence and non-availability of synoptic oceanographic analyses/forecasts. As these analyses/forecasts have now become available to some fishermen, experiences show that they are making as intensive use of them as of navigation charts.

Fisheries planning

In distant offshore fishing there usually is a multiple choice of which principal fishing grounds to fish (e.g. Georges Banks or Grand Banks). Selection of which grounds to fish is made before the trip and can be based on two considerations—availability of fish and fishability with respect to weather. Which consideration weighs heavier depends greatly on the season. A sound and

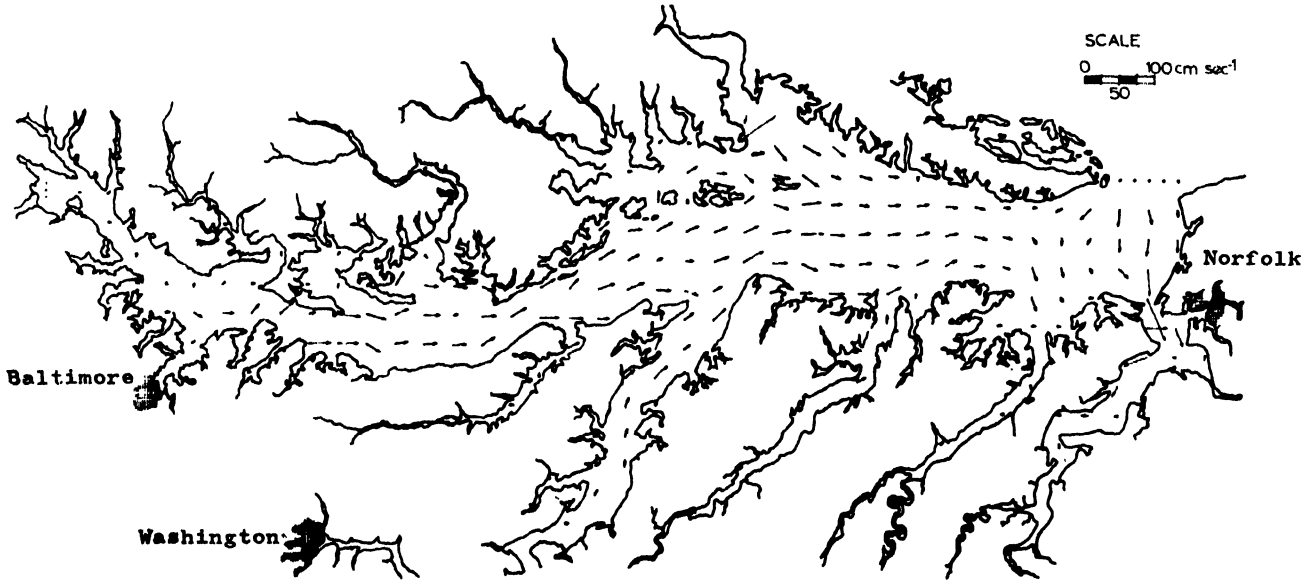

Fig 4. Tidal currents at Chesapeake Bay 4.5 h after high water at Hampton Roads (N wind 7.5 m sec^{-1})

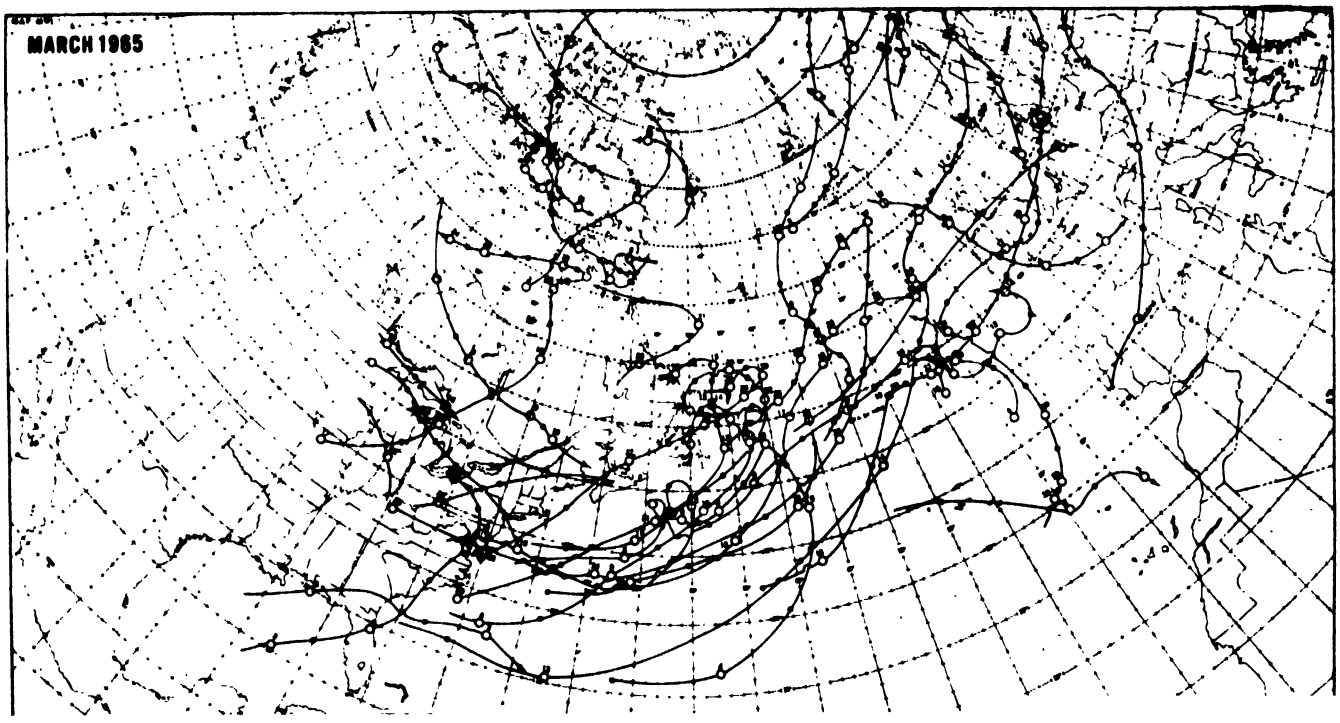

Fig 5. Storm tracks at sea level in North Atlantic March 1965

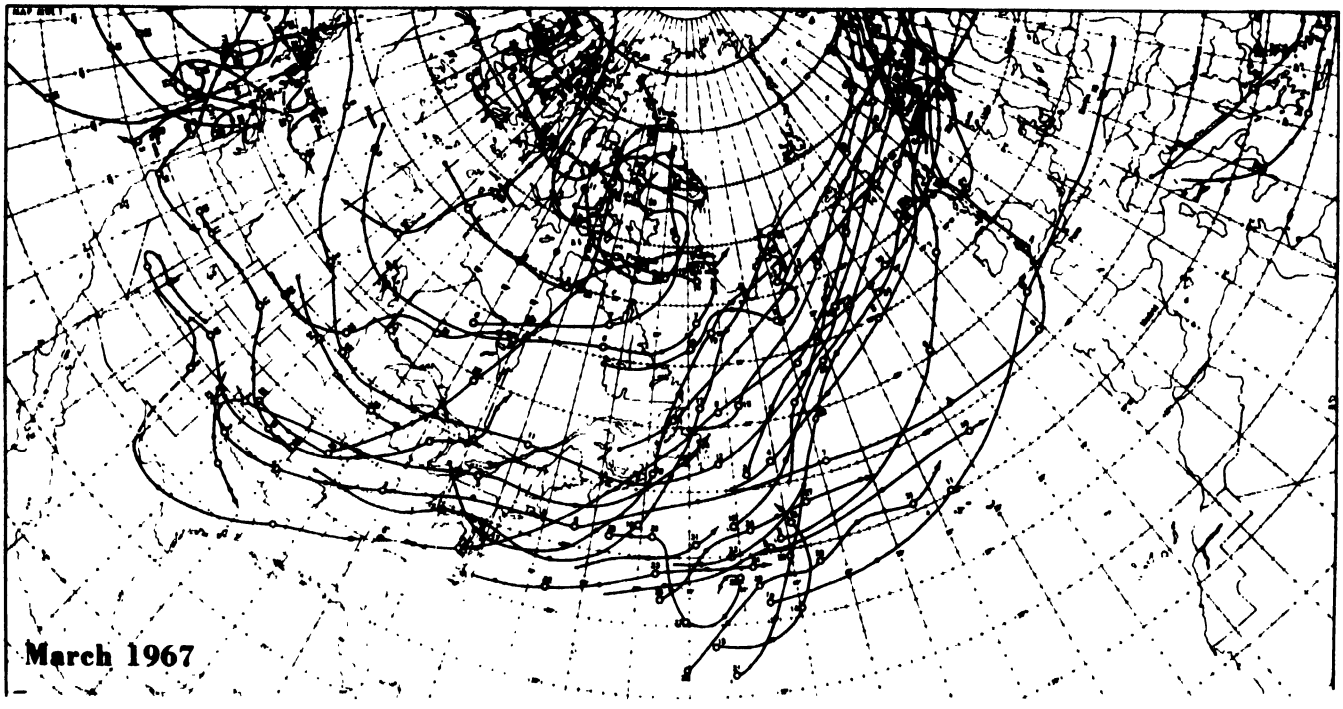

Fig 6. Storm tracks at sea level in North Atlantic March 1967

economic decision can be made if medium and long-range weather and oceanographic forecasts are available.

The year-to-year variability of weather is illustrated with monthly storm track charts for March 1965 (fig 5) and March 1967 (fig 6). It is obvious from these charts that trawlers from Europe probably carried out more fishing on account of weather off Lofoten or in the Barents Sea and possibly in Icelandic waters in March 1965 than on the Grand Banks.

The medium range weather forecasts also provide information for sea and weather routing of fishing vessels and for making such decisions as whether to spend a day or two on the fishing ground or to search for protection in the harbour. The weather forecasts

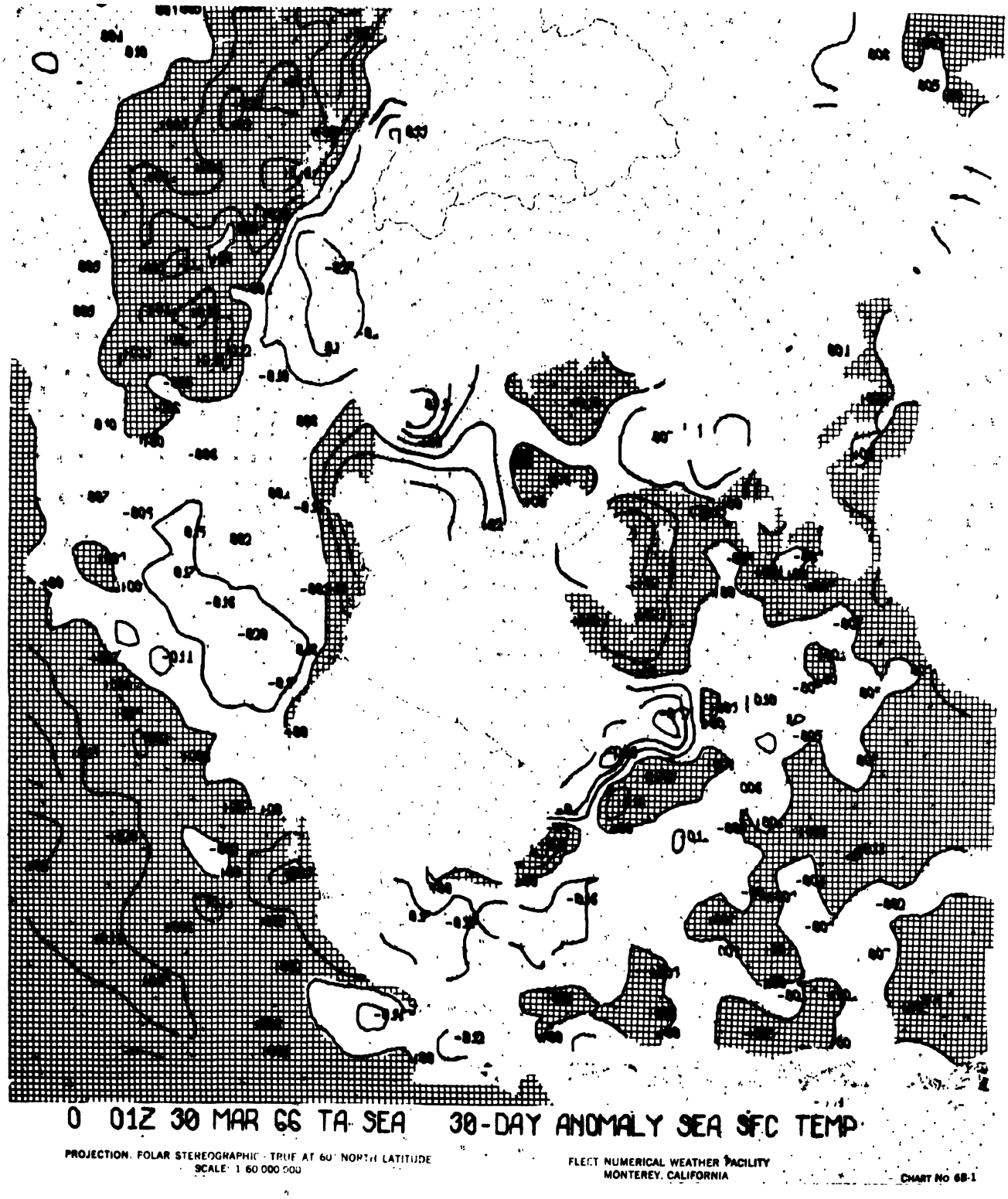

Fig 7. 30-day mean large-scale sea surface temperature (SST) anomalies in March 1966 (positive anomaly areas are cross hatched; 013 means 1.3°C anomaly)

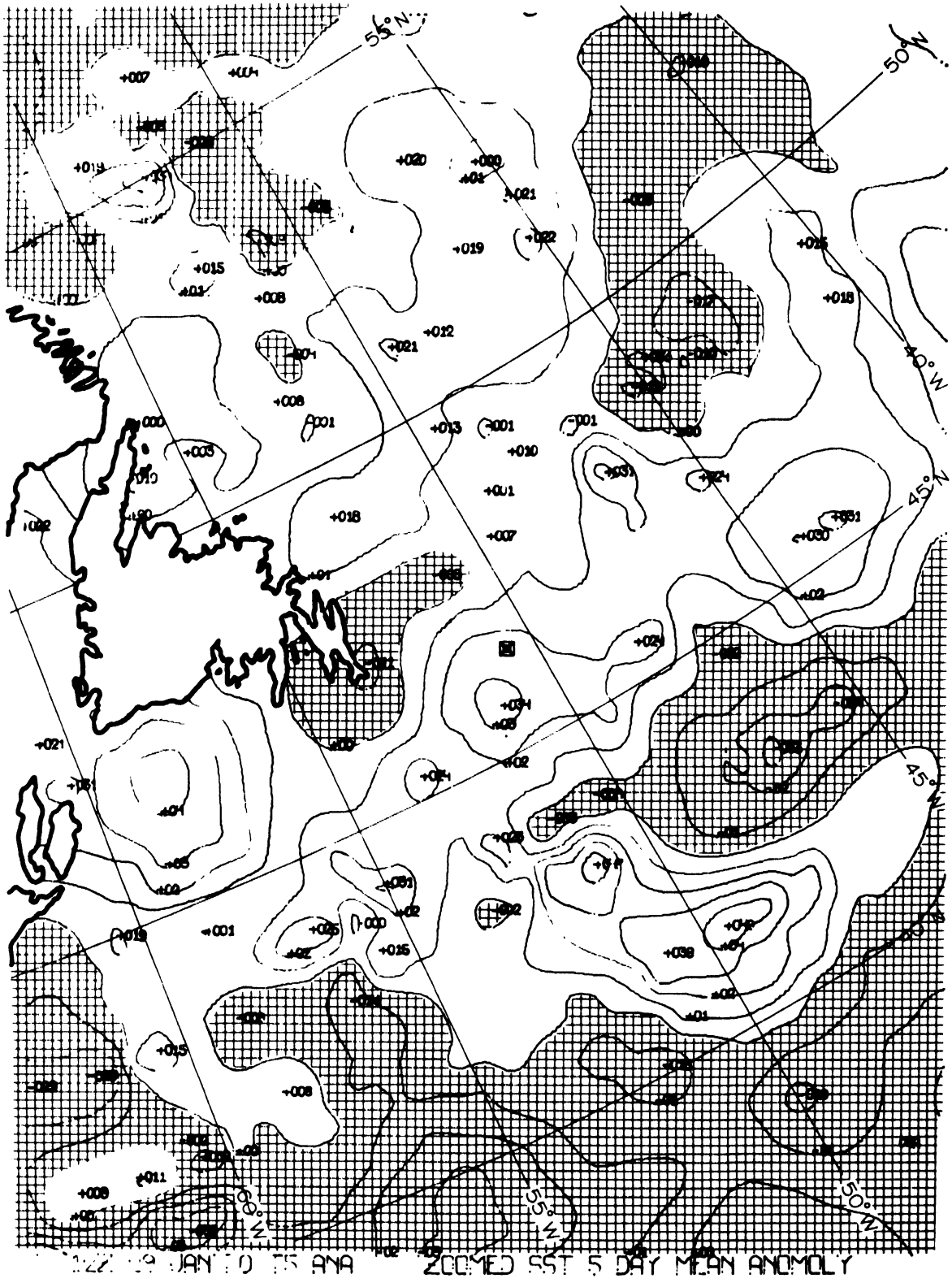

Fig 8. 5-day mean SST anomalies off Newfoundland–Grand Banks area, period ending 29 January 1970 (negative anomaly areas are cross hatched; 010 means 1.0°C anomaly)

(both short term, medium and long range) must be especially tailored for fisheries use. In general, this is not the case at present.

Medium range oceanographic forecasts serve mainly for determination of the availability of fish on different fishing grounds. Of great use is the analysis of large-scale persistent SST anomalies (fig 7) which can be used for fish location as described earlier and also for fisheries planning in a similar manner. The smaller scale analyses of SST anomalies (fig 8) will serve to determine more accurately the grounds to be fished in a general area.

Of other parameters, recent mixed layer depth (MLD) anomalies and analyses of the boundary positions of major currents is useful information in fisheries planning. This information is also used for planning purposes in a manner similar to the use described in Chapter 2.

One of the shortcomings of fishery scientists has been their general lack of understanding on how a good fisherman develops a fishing strategy. The good fisherman is a walking computer, constantly integrating many, many bits of information into a course of action. The fishery scientist for fear of being wrong often withholds information until he is absolutely certain that his data and analysis thereof are correct. This may be depriving the fisherman of the one vital link that he may need in developing a correct strategy. Rarely, if ever, will a good fisherman base his strategy on the scientist's information alone. If the scientist's information is incorrect it may be of no great consequence because of counter-acting information in possession of the fisherman. Probably much greater use would be made by fishermen of synoptic oceanographic and meteorological forecasts, if only they had the information at hand.

ENVIRONMENTAL ANALYSES IN FISHERIES RESEARCH

Little use has been made of synoptic environmental analyses in fisheries research in the past. Two reasons for this are that (a) "fisheries research" has been biologically oriented, rather than application oriented, and (b) synoptic environmental analyses/forecasts have not been available to fisheries.

There are too many possibilities and models for the use of environmental data in fisheries research to list them in this summary article. Reference on this subject is made to the book, *Fisheries Oceanography*, by Hela and Laevastu.

One of the main shortcomings in the use of environmental data in fisheries research has been the attempt to analyse the effects of only one environmental feature on fish behaviour and distribution. The interaction of the fish and the environment is extremely complex and it is obvious that a number of features and processes are affecting fish populations. The availability of synoptic data and forecasts, and the use of high speed computers permits analyses of a number of interacting factors and processes resulting in a more realistic appraisal of fish behaviour and distribution. Furthermore, by asking a number of related questions pertaining to possible interaction, more applied information is obtained. This might be illustrated with a borderline example. Figure 9 shows sea surface temperature anomalies on the North American continental shelf in the area and months of haddock spawning. The first question asked could be: What effect did the anomalies have on haddock year class strength? (In fact, only 1963 had a good year class and was the only year in this group with positive anomaly.) The other questions, of some practical interest, could be: was the haddock spawning displaced and/or delayed in cold years, where and how much? Was the occurrence of other species also displaced to the south? What was the reason for the environmental anomalies and could they have been predicted? There is a need to work up the various accumulated fish-environment relationships in computer compatible form. After this has been done, application of synoptic oceanographic analyses and forecasts may provide useful and timely information on fish behaviour and distribution. Finally, it could be mentioned that the availability of environmental analyses/forecasts will enable a rational planning of fisheries research, e.g. location of sampling and monitoring stations and determination of frequency of sampling and/or observations.

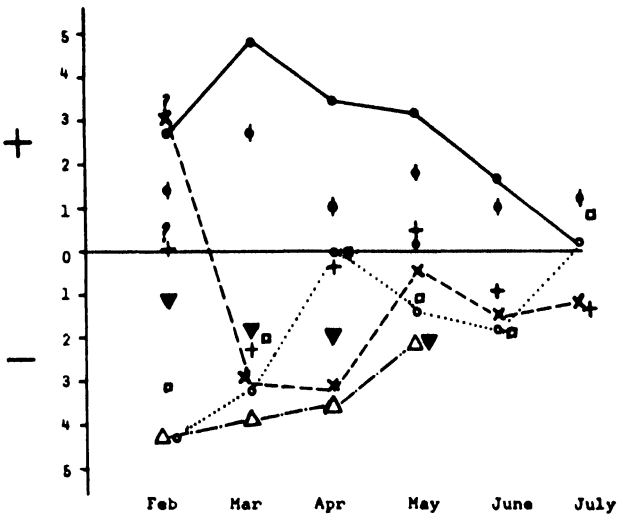

Fig 9. Maximum sea surface temperature anomalies on Grand Banks, Georges Bank and North American continental shelf area from February to July 1963 to 1966

Grand Banks		*Georges Bank*	
○	1963	●	1963
×	1964	+	1964
△	1965	▼	1965
○	1966	□	1966

STATE OF KNOWLEDGE OF FISH BEHAVIOUR IN RESPECT TO ENVIRONMENT

By scanning fisheries literature one finds that a considerable amount of information is available on fish behaviour in respect to the environment. There has also been a surge of research on fish behaviour in respect to gear in the 1960's. This information is, however, scattered in numerous publications and articles with quite different titles which do not necessarily indicate that any consideration has been given to the environment in the

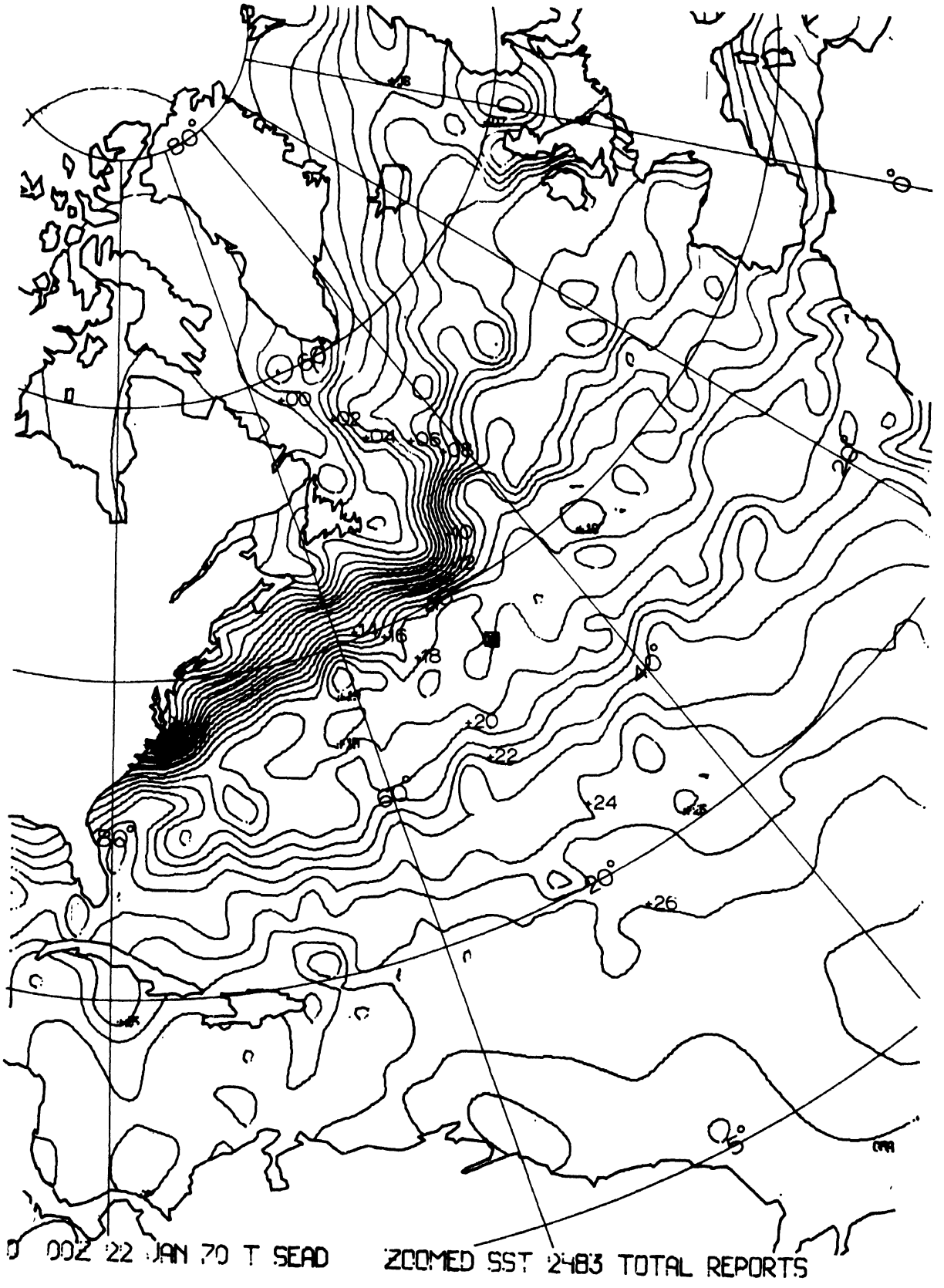

Fig 10. Surface temperature analyses in North Atlantic Ocean

article. Consequently, not much, if any of this valuable information is being applied to fisheries needs. There is a need for summary work on fish-environmental relations on a regional basis. Some beginnings have been made in a more general fashion and with emphasis on some singular factors (temperature, light, currents, swimming speed of fish, etc.). Noticeable is the absence of such simple summaries as charts on spawning grounds, seasons, and spawning concentrations and behaviour of different commercial fish, although a vigorous start on this subject was made in the 1920's and 1930's. Of great practical value for fisheries and fisheries forecasting would be condensed regional summaries on temperature and depth preference of different species in different seasons.

Although shortcomings exist, there is a sufficient amount of detailed information available to be used as a basis for fisheries services and forecasts.

PRESENT STATE OF OCEANOGRAPHIC AND METEOROLOGICAL FORECASTING

Synoptic oceanographic analysis has made considerable progress in the last five years. Many of the developments, results, and implications have not yet filtered to all groups who can benefit from them. Progress in synoptic oceanography and oceanographic services has mainly been caused by (a) increased naval use of this information and (b) use of large high-speed computers to accomplish the task. The rate of acquisition of oceanographic data has, however, not increased noticeably, with the exception of the introduction of XBT's in the last few years which is comparable in effect to the introduction of radiosonde in meteorology after the second world war. The progress in medium- and long-range weather forecasting has been slower than expected, although some breakthroughs can be expected in the near future from a numerical computerized approach. Only a few oceanographic parameters lend themselves to direct analyses (e.g. SST, waves) based on synoptic observations from voluntary observing and reporting vessels. Most other oceanographic analyses must be computed from driving forces (meteorological) and the knowledge of their effects on the oceans.

An example of synoptic SST analysis is shown on fig 10. It should be noted that the accuracy of this analysis in different areas is dependent on the density of synoptic observations and the scale of analysis. Several accurate small-scale analyses with 20 n mi grid size are carried out at FNWC in Monterey. This is the smallest grid size justified by the density of the observations.

Examples of 36 h subsurface thermal structure forecasts at four defined points in the Pacific Ocean are shown in fig 11 as BT traces. These forecasts contain in coded form information on short-term fluctuation of MLD, thermocline tendency and gradient in thermocline. Many other synoptic analyses/forecasts are now made routinely, such as MLD, surface currents, current boundaries, heat exchange, etc.

The greatest breakthrough in the last few years in oceanographic analyses/forecasts has been the application of Hydrodynamical Numerical models, although

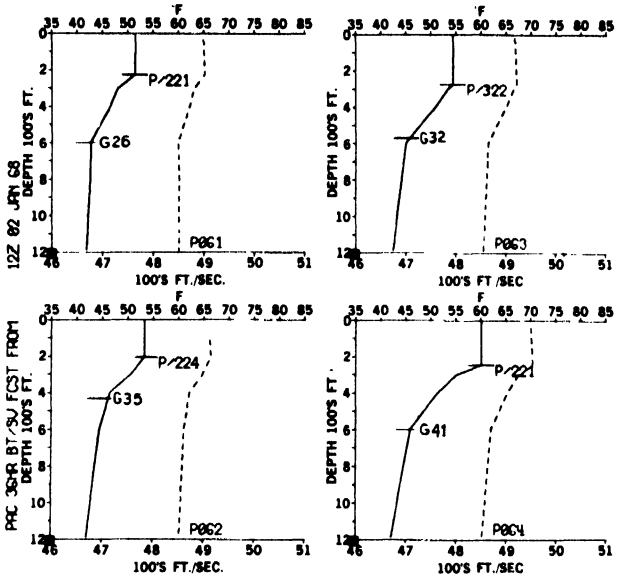

Fig 11. Example of thermal structure forecast at four different locations

these models were developed and their utility demonstrated a few decades ago by Professor W. Hansen in Hamburg. The availability of large computers has made the use of these models realistic and economical.

The fisheries environmental services are in their infancy. There are clear indications that if existing fisheries research organizations do not provide the services, the fishing industry will do so itself.

DISCUSSION

LOCATION OF FISHING GROUNDS

Laevastu (U.S.A.) Rapporteur: To help fishermen catch more fish, more efficiently, seems to be a rebellious action in the light of conservationist thinking now prevailing. However, the fishing industry has the same right to bring its cause to the fore.

As you know, traditionally a great part of fisheries research has been engaged with what is termed "basic research for design of conservation measures" the purpose of which often appears to be for the researcher to get a paper published in the professional press to impress colleagues. The content of that paper is usually presented in a jargon entirely foreign to those concerned with fishing and the fishing industry. However, in many quarters the support for fisheries research programmes is rapidly dwindling and pressure is put on fisheries agencies to provide various other services to the fishing industry.

Obviously fisheries services in various forms have existed for some time in a number of countries. An excellent review of such a service in Iceland is given in **Jakobsson's** paper.

The three basic ways to help fisheries are:

1. **To improve gear,**
2. **To improve vessels,**
3. **To direct the fishing fleet to large concentrations of fish.**

The first part of this conference is concerned with the third item which might be called fisheries forecasting. It should be

emphasized that each service in this field must be designed and tailored to specific prevailing conditions. The papers given, which serve as examples and sources of ideas, are in condensed form and it is unnecessary to summarize them here. Instead, I present a few problems for general discussion. The first three are raised by **Jakobsson** in his paper:

International versus national services. Obviously some general, large-scale services are possible in international (mainly regional) areas, but the bulk of services must be national or even company services, due mainly to economic competition.

Single fishery versus multi-fishery services. I agree with **Jakobsson** that a multi-fishery service is considerably more rational than a single-fishery service.

Improvement of ship to shore and ship to ship communications. The success of fisheries services depends largely on the improvement of present communication facilities, both on ship and on shore. This includes the installation of facsimile recorders as well as strip printers.

Among additional problems closely connected with fisheries services are:

(a) Should fisheries be combined with research, and how large a proportion of present fisheries research should be involved with fisheries services. The general unwillingness of "research people" to engage in services should be noted here.

(b) A need for extension services to fisheries, including ways and means of briefing and arranging displays in simple everyday language.

(c) A need to provide proper observing instruments to fishermen. In the past fisheries scientists have been mostly concerned with constructing gadgets for themselves, with few notable exceptions.

(d) Numerical physical and statistical modelling of environment and environment-fish relations for improving forecasting methods.

Finally, it should be emphasized that fisheries forecasting services should form an important integral part of dynamic fisheries regulations, based on proven scientific knowledge and principles, so that fisheries can be regulated variably in space and time, depending on conditions, migration and other behaviour of stocks and environment affecting them.

Jakobsson (Iceland): Following the Rapporteur's remarks on national versus international fish location and search surveys, I would like to draw attention to the fact that in some countries, such as the United States and Chile, location and search services are carried out not on a national but on a company level.

With reference to environmental data—especially that of plankton, which can be of use in herring location work—I will summarize. Generally, we find herring (out of the spawning season) near or within the boundary areas of the warm Atlantic and the cold Arctic currents. Within these areas the distribution of plankton is closely correlated with that of herring, especially during the intense feeding phase of herring in spring and early summer. Often the density gradients are of more importance than the actual quantity of plankton. By studying the age composition of the main herring food plankton animals, especially the species *C. finmarchicus*, one can forecast the development of food concentrations and thus indicate future trends of herring migrations one to three weeks in advance. These studies must, of course, be carried out daily at sea in order to use them in forecasting.

I am very interested in the Eureka programme described by **Villanueva** in which a large number of chartered fishing vessels are used to cover the entire fishing area in one day. This gives a very clear picture of the situation which I am sure is of great help, although I would think in addition one would need to follow the development of the migration patterns by using special search vessels over longer periods as we do in Iceland, a method I refer to as continuous or uninterrupted pursuit.

Villanueva (Peru): Said he had been considering methods of survey rather than results.

Valdez (Portugal): Underlined the need for support from fishermen and their acceptance of guidance from the scientists in planning a survey. Support from the owners was also needed. Fishing vessels, when making a survey, would naturally stop surveying and start fishing as soon as they had located fish in acceptable quantities. To prevent this, crews of scouting vessels were kept small so that the vessel could not fish. If a fisherman doesn't get information on where the fish are, then he does not highly regard either the survey or those making it. Speaking of Peru he said that anchovy prefer to lie in the mixing layer just above the thermocline. Later surveys in Peru organized by the FAO Fisheries Project took place at the request of boat owners. Total collapse of landings during July and August 1964 was avoided by employing vessels on scouting and thus keeping contact with the fish.

In Angola he tried the same methods as those used in Peru, but it turned out to be not so easy in practice. Before planning a survey it is necessary to have considerable knowledge of the environmental factors in the area and it is also necessary to know something of fish behaviour in the area.

Jakobsson (Iceland)—(written contribution)

The whole basis of rational fish location work, as opposed to more or less random fish search, is that of utilizing environmental factors such as temperature and plankton density gradients in order to estimate the distribution and subsequent movements of fish migrations and the resulting changes in fishing areas. To illustrate how this works in practice I present two figures, one showing the situation during the Icelandic summer herring season in June 1962 the other in June 1965.

In 1962 the 5°C isotherm at 20 m depth generally was about 50–60 nm off the north coast (fig A top left) and the whole coastal area of east Iceland generally had a temperature, at 20 m between 4 and 5°C. The zoo-plankton density chart (fig A, top right) shows that there were two main food concentrations: one off the western and centre north coast, the other off the east coast. Judging from these environmental conditions it was very probable that the June and July catches would be taken south of the 6°C isotherm (fig A, top left) and especially along the main plankton density gradients, as these would develop during the period in question. It was further possible to forecast that conditions for herring fishery generally would be favourable off the north and east coasts in July 1962 and that probably catches would be highest off the north eastern coast and east of Iceland. The latter forecast was based on age analyses of the dominant zooplankton copepode (*C. finmarchicus*) which showed that in the last-mentioned areas large concentrations of this species were developing and would reach their maximum during July. The *pro mille* distribution of the June and July herring catches in 1962 as charted in fig A (bottom left and right) shows that fishing at the beginning of the season, in June, took place almost entirely at the western edge of the plankton density gradients and between the 5°C and 6°C isotherms. This fishing was based on Icelandic herring which had spawned off SW Iceland in March–April and had reached the feeding areas off the north west coast in June. The herring which migrated from Norway towards the more eastern fishing areas was already

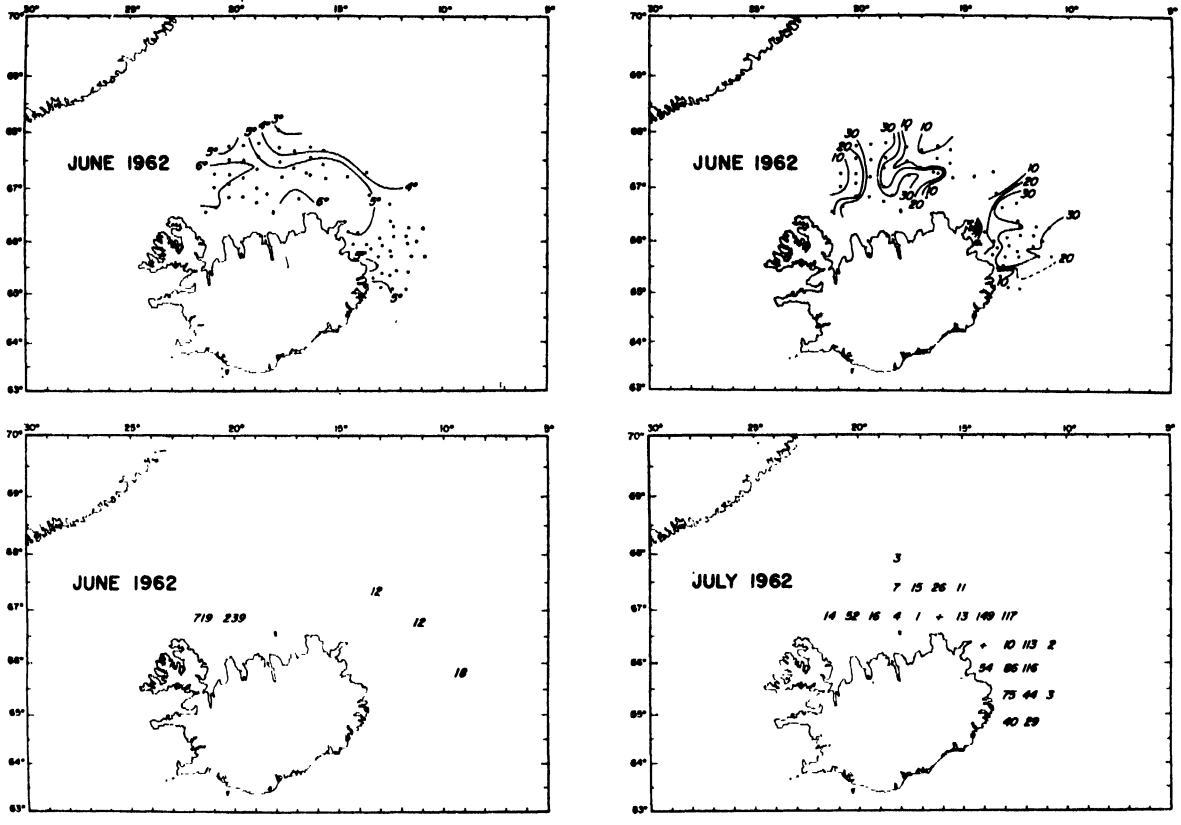

Fig A. Environment factors and distribution of herring catches 1962.
Top left. Temp at 20 m. Top right. Zooplankton gradients drawn at 10, 20 and 30 ml per 20 m³ of sampled seawater using vertical Hensen net. Bottom left. Pro mille distribution of the Icelandic herring catches in June 1962. Bottom right. Pro mille distribution of the Icelandic herring catches in July 1962

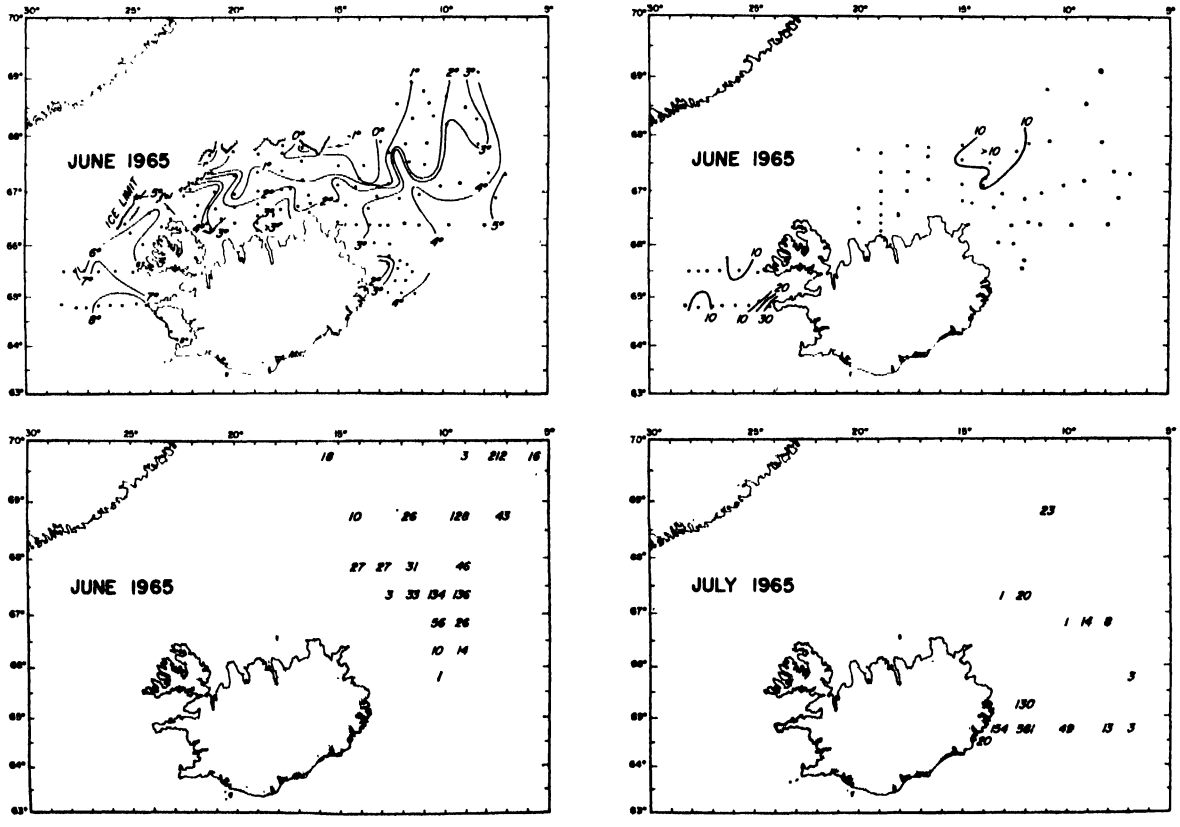

Fig B. Environmental factors and distribution of herring catches 1965 arranged as in Fig A.

present in June but fishable schools were then only formed sporadically. As forecast for July 1962, fishing took place in large areas off north and east coast (fig A, bottom right) mostly near the main plankton density gradients.

The environmental charts for June 1965 (fig B, top left and right) are very different from those of 1962. The temperature off the north and east coast at 20 m depth was generally 0–3°C in 1965 as compared with 5–6°C in 1962. Similarly, no plankton concentrations were observed off the north coast in 1965. The whole area appeared almost void of herring food with the exception of a slight indication of a plankton concentration in an offshore area north east of Iceland. This made it extremely unlikely that any herring could assemble and become fishable off the north coast and therefore search vessels could be directed to other more promising areas. The development of the north coast areas later in the summer was, however, kept under observation for scientific and other purposes. As expected the *pro mille* distribution of catches in June and July 1965 are in close correlation to the drastic changes in environmental factors as compared with 1962. Thus in 1965 no fishing took place off the north coast. Instead, catches in June were taken in oceanic areas (fig B, bottom left) and in July the little fishing that took place was mainly concentrated off the south east coast where temperature and plankton gradients (not shown in fig B) had developed in July. These illustrations clearly show the striking correlation between environmental factors and fishing areas and the subsequent benefit of a thorough knowledge of these factors to a rationally planned fish location tactic.

Sigtryggsson (Iceland/WMO)

I wish to express appreciation to the Food and Agriculture Organization for having offered the World Meteorological Organization an opportunity to participate in the deliberations of this important conference.

References have repeatedly been made to long, medium and short term forecasts of meteorological elements affecting fishing operations. As these forecasts can only be made with the help of a world wide organization for data gathering and distribution, I will give a brief resumé of the activities of the WMO in this field.

One of the constituent bodies of WMO, the Commission for Maritime Meteorology, has been very active in the consideration of problems of services to fisheries. The fifth meeting of their Commission, held in 1968, suggested that Member States of WMO be encouraged to assist the fishing industry, when economically warranted, by the provision of information on sea surface temperature (SST) and mixed layer depth. This suggestion was supported by the Executive Committee Panel on Meteorological Aspects of Ocean Affairs, which further recommended that the temperature distribution down to the thermocline, and the depth of the thermocline be included.

Marine climatological information including sea temperature pattern, has long been used in the planning of various aspects of pelagic fishing. WMO, being keenly interested in providing such information to marine user groups, is now undertaking two major projects relating to the compilation of marine environmental data, i.e. Marine Climatological Summaries Project from 1961 and onwards, and the Historical Sea Surface Temperature Data Project covering the period from 1860 to 1960, for data of SST, wind and humidity. Certain national Meteorological Services have also prepared similar summaries for specific sea areas.

WMO will therefore welcome any suggestions and comments for improving meteorological services in this respect.

Giving a personal opinion, he thought that weather forecasts have to be specially tailored to fisheries and believes that there is much to learn from the aviation weather service. One important factor is the information from operators. Weather forecasters must have practical information in order to improve the service.

Ben-Yami (Israel): In Israel we shall shortly begin measuring the sea surface temperatures using infra-red radiation sensing from aircraft. Could anybody who has experience in using such instruments express his opinion on the subject?

Laevastu (USA) Rapporteur: The Fleet Numerical Weather Central has had experience with IRT sea surface temperature (SST) data. Instruments tend to drift from calibrations, and so frequent calibration is necessary. Furthermore, this method cannot be used in bad weather through clouds or fog. However, relative values can be used, if observations are made in clear weather. The operation is also expensive if one has to hire an aircraft. My experience is that the accuracy of satellite IRT SST is nearly one order of magnitude lower than desired for a good SST analysis

Laevastu (USA) Rapporteur, summing up: We have not mentioned the fisheries environmental services provided by various Japanese fisheries agencies and companies. In Japan we find many examples of company services. The reasons are obvious—fishing is a very competitive business there.

Fish concentrations are not static, as pointed out by **Jakobsson**. One-time or infrequent sonar services are useful to ascertain the presence and abundance of the stocks in a given area, but these spot surveys do not say anything about the future movement of schools. Thus there is a need for a continuous advisory service to the fleets. This can be done by prediction of the changes in the environment as shown by several papers presented to this Conference.

Such a service requires close cooperation between meteorologists, oceanographers, fisheries scientists and, above all, fishermen. The latter must be able to report back confidently both the environmental observations and catches without fear that the latter information falls into the hands of competition.

It has been noticed with pleasure that meteorologists are willing to tailor forecasts to fisheries. Furthermore, it should be noted that meteorology and meteorologists are playing a key role in fisheries forecasting as they predict the driving forces of the ocean and possess a communication system.

Several contributions highlighted two aspects related to fisheries forecasting services. First, that results (whether positive or negative) would be extremely useful in furthering our knowledge of the fish-environmental relations so that fishermen can make effective use of this knowledge in their daily work. Secondly, fisheries forecasting services would provide a basis for dynamic fisheries regulations. One cannot emphasize too strongly that fisheries regulations should be based on sound scientific information and should be designed for the benefit of fishermen and not to put them out of business as do most existing regulations dictated by politicians.

Southeastern Pacific Aircraft-assisted Purse Seining

by M. Sams

Pêche a la senne tornante dans le pacifique du sud-est a l'aide d'avions

Durant les 20 dernières années, les avions ont acquis une importance croissante pour détecter les poissons de surface et fournir des instructions directes aux patrons pêcheurs durant les opérations de pêche à la senne tournante, à tel point que certaines pêcheries importantes font reposer leurs opérations entièrement sur eux. Pour avoir un rôle vraiment efficace, le pilote chargé de détecter le poisson doit connaître parfaitement la zone d'exploitation et les opérations de pêche auxquelles il participe, et pilote et patron doivent travailler en équipe. On détermine généralement la répartition du poisson le jour précédent et les bateaux de pêche sont ensuite guidés par le pilote jusqu'aux bancs. Il arrive aussi très souvent que le pilote oriente les opérations de pêche à la senne tournante en fonction du comportement et du mouvement des bancs de poisson et signale si l'importance des stocks nécessite une séparation des embarcations. Les bancs de surface peuvent être détectés à l'oeil nu jusqu'à une quinzaine de mètres de profondeur et les espèces de poisson peuvent souvent être distinguées d'après leur couleur. On peut également déceler depuis l'avion le plancton, les courants et les lignes de démarcation entre les diverses masses d'eau. Compte tenu de l'expérience acquise au cours des opérations commerciales, l'emploi d'avion ou d'hélicoptères est recommandé pour la prospection des poissons de surface et activités connexes, de préférence en association avec des navires de recherche.

Pesca con redes de cerco de jareta y con ayuda de aviones en el pacífico sudioriental

Durante los 20 años pasados los aeroplanos han adquirido cada vez más importancia para la localización de peces en la superficie y para orientar directamente a los patrones durante las operaciones de pesca con redes de cerco de jareta, y hasta tal punto la han adquirido que algunas pesquerías importantes confían casi completamente en ellos. Para realizar eficientemente su trabajo el piloto que trata de localizar a los peces debe poseer un profundo conocimiento de la pesca y de las operaciones pesqueras a las que sirve, y el piloto y el patrón han de trabajar en equipo. Después de haber determinado el día antes la distribución de los peces en general, el piloto guía a las embarcaciones pesqueras a los cardúmenes. Con mucha frecuencia el piloto dirige también la operación de la red en lo que respecta al comportamiento y movimiento de los cardúmenes y advierte si la cantidad de la captura exige dividirla. Los cardúmenes de la superficie se pueden detectar a simple vista hasta una profundidad de 15 m, pudiéndose distinguir frecuentemente por su color las especies de peces. También se pueden detectar claramente desde el aire el plancton, las corrientes y los límites entre las masas de agua. Basándose en la experiencia obtenida en las actividades comerciales, se recomienda el empleo de aeroplanos o hilicópteros para los reconocimientos de los peces en la superficie e investigaciones afines, preferiblemente en combinación con barcos de investigación.

DURING the past 20 years there have been numerous important technological developments—the power block, hydraulic winches, fish pumps, synthetic materials and sophisticated electronics for better fish detection. Perhaps the least known addition to this list is the aeroplane.

Aeroplanes are not new to the industry. They have been in use for over 20 years, assisting fishing fleets in reducing search time. However, their importance has increased in the last 10 years and they are now a vital factor in most of the anchovy and sardine fleets of Chile and parts of Peru. They have played a big part for many years in the great menhaden fleets of the United States and the California sardine industry, and are today so important to most tuna seiners that their use can mean the difference between success or failure.

THE FISH-SPOTTER PILOT

The fish-spotter has ceased to be just a pilot. As the years passed people began to realize the importance of the search planes and the spotter pilots. As a result a completely new breed of highly trained and well paid professional flying skippers was developed from intelligent pilots who possessed a dedication towards commercial fishing. These men soon became essential to their companies.

The captains and pilots must form a close working team because each captain must trust his "airborne eyes" without question. To reach this point of confidence, a fish-spotter pilot must not only know his job in an aeroplane or helicopter, but has to know the skipper's job as well. Most of these pilots will have spent quite some time aboard fishing boats and have conducted actual fishing manoeuvres under the supervision of a top captain, worked the echo sounders and sonar, exchanged points of view with the crew members and in general have done everything possible to gain fishing knowledge and their working partners' confidence. Once he has this confidence, the pilot can manoeuvre the fleet safely and effectively without having to expose his tactics to competition.

EQUIPMENT

In the South American anchoveta fisheries, for safety and endurance mostly twin engine aircraft are used. The make and models vary considerably depending also upon local availability. Some fishing industries use charter planes and pilots while others operate their own machines and hire pilots according to their needs. The chartered pilot is paid by the flying hour and usually an incentive is lacking, whereas the company pilot has a direct participation in the catch.

An aeroplane must meet several requirements for this type of work. Excellent visibility is a "must"; this means unobstructed view from left to right to a minimum of 180° and an unobstructed vertical view port and starboard. This factor alone has made it possible to detect fish concentrations not noticed by others flying less adequate equipment. Aeroplanes of a high wing design have so far proved themselves best, providing the wing is located aft of the pilot's seat so that the engines are not in his line of vision. None of the low wing models

meet this requirement. Ease of operation through stability and manoeuvrability are important because a tired pilot will not be able to produce well. Adequate fuel capacity and endurance are vital. An aeroplane should remain airborne no less than 8 h. When more than one aeroplane is operated by a company, usually the "scouting" aeroplane is the one that meets all the desired factors, as it is this machine that directs the "boat setting" aircraft to the area of the fish where they take on the task of setting the vessels around the fish schools.

In the South American anchoveta fisheries the aeroplanes must all be equipped for instrument flight. This is even more important for aeroplanes carrying out whale and tuna operations because most of the time they are not in sight of land so must be able to provide accurate position fixes for the fishing vessels. The anchoveta spotter-pilot in Peru and Chile needs the instrumentation for his own navigation and safety, not for guiding vessels, because most of these boats are equipped so far only for a position report in terms of land marks and distance off-shore.

In the United States menhaden industry, the number of aeroplanes used per fishing boat is greater than in Chile and Peru. Their system depends on a very reliable scout plane which is usually of the twin engine type and generally flown by the chief pilot. The setting aeroplanes consist of the most varied assortment of single engine machines. There is a prevailing custom in certain companies that a top captain has an aeroplane for the use of his boat alone.

The communications between planes and boats vary according to area, company and country. In most of South America high frequency (HF) communication systems are used; however, this will soon be obsolete and in the near future communications will only be carried on with single side band equipment (SSB). In the United States, the use of frequency modulation (FM) units is prevalent; this gives a much clearer communication but sacrifices in range. Permanent aircraft-to-aircraft communication in the Chilean commercial fisheries is carried out with very high frequency (VHF) on 118.5 MHz. This is a mandatory safety regulation and has proved very sound.

Midair collision hazard in this type of flying exists, especially when many aeroplanes concentrate in the same area (sometimes ten or more planes). To lessen this hazard, different flying levels are agreed upon between the pilots before take off and through the common VHF communication. Bright strobe lights have been installed by some plane owners to replace the rotating-type beacons.

The helicopter is starting to interest many people in the fishing industry, because of its ability to land and take-off vertically. Some tuna boats carry their own helicopter on board. For years, helicopters have been very expensive to operate, their reliability was somewhat questionable and they were difficult to manage. Today there is a new class of machine—turbine-driven helicopters. Their speed is up, reliability is good, time between maintenance requirements reduced and ease of operation excellent. With these machines new developments may occur.

THE FISHING OPERATION

Anchoveta

The spotter pilot is the person to suggest or determine where the fishing fleet will work. After his reconnaissance, he files a written report of the areas flown and how much fish and what species he has observed. He suggests and discusses the next day's operations with the fleet manager. Each captain will determine his sailing time according to the pilot's report.

The fishing aeroplane is airborne in the very early hours of dawn to meet the fleet on the grounds recommended. Once the fish are located, the pilot immediately proceeds to manoeuvre his fleet to reach the fish ahead of others. There are effective tactics to do this. Some simply use naval manoeuvres to outsmart the competition, by making everybody head on a course that will not take them directly towards the fish; but as soon as he has his own boats at an advantageous abeam position, he will make them change course suddenly, thus gaining time and distance towards the goal. Codes have been invented to pass on messages, but these do not always work well. Any kind of lead is advantageous, sometimes a few metres with the boat in the proper position to set is enough.

The setting of vessels individually is preferable to setting a number simultaneously. The pilot moves the boat into position alongside, ahead or beside the fish, instructs the skipper when to start the set and continues directing him all through the set. He may instruct him to make a wide and open net to let the fish swim into the net, or to close up fast if the fish are wild and tend to change course or back out of the net. Once the net is closed and pursed, the pilot usually advises the skipper whether or not he should split the catch into the two bunts. If the catch is too large, there is a risk of losing it due to parting of the seine under the heavy weight. Anchoveta occasionally dive, resulting in damage to seine and rigging and loss of catch. This is less of a problem in shallow water.

Schools of anchoveta are usually located by the colour they show in the water. Most of the time, when conditions are very good, the colour will be of an intense purple and observations of schools as deep as 15 m have been made. On other occasions, depending upon light, water conditions or plankton occurrence, the shades of colour can vary considerably and when schools are down it is very hard to detect them.

When searching for fish, any unusual conditions may indicate their presence; thus it is important to investigate every abnormality observed. The confluence of water masses that tend to concentrate plankton are likely locations for anchoveta occurrence; when birds are observed, pelicans and gannets are the more reliable ones for indicating the presence of anchoveta.

Mackerel, horsemackerel and bonito

The techniques to locate these species vary to some extent from that used for anchoveta and/or sardine. The search area that must be covered is much greater because these are fast-moving fish. They may be visible at one time and then disappear completely the next moment. They are generally to be found at greater distances from the coast and the schools can be detected by colour dis-

tinctions. The shade of colour in standard climatic conditions is usually rust which will vary in intensity depending on whether the fish are moving on the surface or deeper. The "whipping" of mackerel is one of the most intense of any species of fish and is seen usually during the very early morning hours. Later the intensity decreases and normally the fish disappear from the surface a few hours after sunrise.

During the first part of 1970 there was a vast concentration of mackerel and horsemackerel along the northern coast of Chile, to such an extent that on many days when it was impossible to work the anchoveta schools along the shore the anchoveta fleet was used to catch mackerel. In this situation the value of aeroplane assistance was graphically demonstrated. It was extremely important that the pilot remained above the vessels to advise them when to divide the catch into two bunts; 80 per cent of the boats that did this loaded themselves to full capacity from the first bunt and turned the remainder over to another boat. Most of these boats were of 140, 180 and 200-ton capacities. The difference in the catch of the aeroplane-assisted vessels and those without or with a pilot unfamiliar with the habits of these species was striking. This was because the fish were undetectable from the vessels after they had ceased "whipping" in the morning.

The main difference in the showing of mackerel and horsemackerel is that the former are not necessarily accompanied by birds whereas horsemackerel are usually followed by small white doves and a greyish fast-moving gull—the same as is found with bonito and tuna. Horsemackerel will also show colour although of much less intensity than mackerel; they do not "whip" as vigorously and have the same water-cutting action as bonito when breaking the surface.

Bonito is commercially sought for canning; consequently there are entire fleets working this species. They are usually spotted by an unmistakable water-splashing action and reflection when breaking the surface. When in tight schools they also show a light shade of colour and, if the pilot carefully adjusts his altitude above the school, he can clearly determine that it is made up of larger fish because the colour pattern is distinctly freckled.

AERIAL SURVEYS AND RESEARCH

As a result of spending thousands of hours flying over fishing areas of different countries searching for, watching, chasing and hunting fish, a realistic appraisal of this technique for exploratory surveys and research is now possible. With aeroplanes or helicopters large areas can be surveyed efficiently in less time than is possible with other methods. The author has conducted such work successfully out of Mar del Plata, Argentina, the entire Pacific and Atlantic coast of Colombia, and the Gulf of Arauco in southern Chile. The survey in southern Chile was particularly rewarding because of its effect on development.

Naturally a single survey is of only limited value. Because of the changes in environmental conditions and resultant fish distribution, such surveys should be repeated during different seasons of the year to establish whether there is a cycle and at what period the fish concentrations reach their peak.

From an aeroplane plankton concentrations and distributions can be detected, even with differentiation of colour (red, green, mud-like, etc.). Similarly water currents along the coast and offshore can be distinguished; their edges often have a bearing on fish distribution. Surface water temperatures, which also are of influence on fish distribution, can now be measured from aeroplanes with infra-red instruments. The newest survey method is infra-red photography which enables the detection of fish concentrations in depths where they are invisible to the naked eye.

With a helicopter more detailed observations are possible by, for instance, hovering over a certain area or even by going down to the water to collect samples of plankton, water, temperature measurements, etc.

The ideal complete survey would be the combined operation of such airborne methods with a research vessel, the choice between the two types of aircraft depending on the purpose. The main advantages of an aeroplane are higher speed and greater range; the helicopter, on the other hand, is more versatile for detailed observations and can even be operated using the research vessel as a base.

Fish Detection Through Aerial Surveillance

by J. A. Benigno

Detection des poissons par controle aerien

Ce document résume la recherche d'instruments et de techniques au moyen desquels le Bureau des Pêches Commerciales des Etats-Unis peut localiser et évaluer d'une manière plus efficace les bancs de poissons pélagiques. Historiquement, les recherches sur la présance et la dispersion des stocks exploitables ont été réalisées à partir de beateaux se déplaçant lentement et couvrant seulement de très petites parties de la surface des océans. La technologie nouvelle de mesure à distance contribue à des recherches susceptibles de révolutionner la détection, l'identification et la quantification des bancs de poissons pélagiques. Les études du Bureau ont progressé depuis les observations visuelles en vol à basse altitude jusqu'à la photographie à haute altitude, l'exploration spectrale multiple et les lasers. Nous avons même observé des bancs de poissons par avion de nuit en utilisant des appareils sensibles aux basses intensités lumineuses capables de détecter les poissons par leur luninescence. On entreprend actuellement des travaux sur la réception, le traitement et la diffusion des données acquises en mettant l'accent jusqu'ici sur l'analyse et l'interprétation des transparences photographiques et des bandes magnétiques. Le but final est de mettre au point un système aérospatial sensible à distance capable de recueillir et de diffuser les données d'une manière immédiate et synoptique.

Detección de peces mediante observaciones aereas

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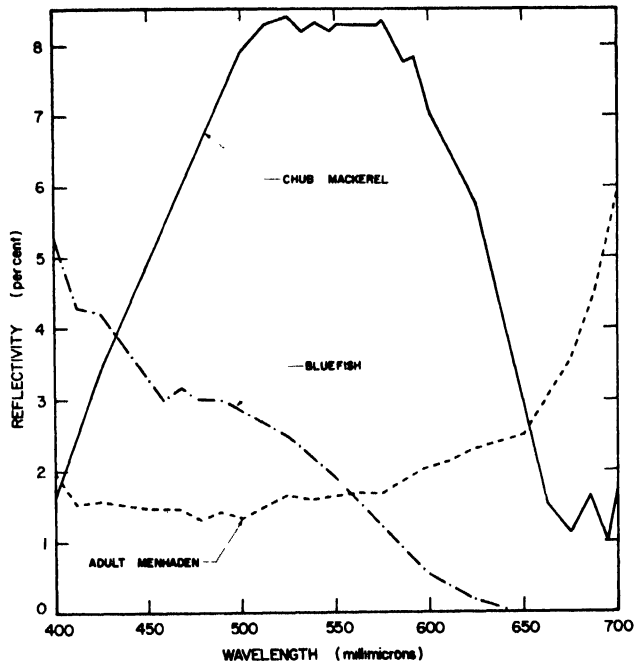

Fig 1. Spectral reflectivity curves for chub mackerel, bluefish, and menhaden

We had the opportunity to test standard photography for identifying and quantifying pelagic fish schools when a thread herring fishery went into production along the west coast of Florida. The Bureau and industry co-operated to coordinate aerial photography and harvesting of fish schools, thus obtaining ground truth controls for the aerial imagery. Fishery biologists were aboard the fishing boats to obtain quantitative and qualitative samples of the catch. Additional samples of other species in another area were obtained for comparison by Bureau personnel.

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MULTISPECTRAL PHOTOGRAPHIC EXPERIMENT

In addition to standard aerial photography for species identification, we used a multispectral photographic system to detect and record the spectral signatures of fish schools. Experiments were conducted by Long Island University Science and Engineering Research Group, through a Bureau of Commercial Fisheries' contract, to determine and identify the spectral bands that would penetrate local waters and enhance the fish school imagery. Spectroradiometers were used to measure incident sunlight, downwelling light, and per cent transmission of light in water at selected stations in the northern Gulf of Mexico. As a result of the radiometric measurements, filters were selected for a four-lens multispectral camera. Flights were made using the multispectral system to photograph artificial targets and fish schools.

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Radiation measurements of oil slicks indicate that fish can be detected by monitoring sea surface temperatures. Measurements of oil slicks, in the 8 to 14 band, have shown temperature differentials of 1°C between the fish oil film and the surrounding sea surface.

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Fish Detection Through Aerial Surveillance

by J. A. Benigno

Detection des poissons par controle aerien

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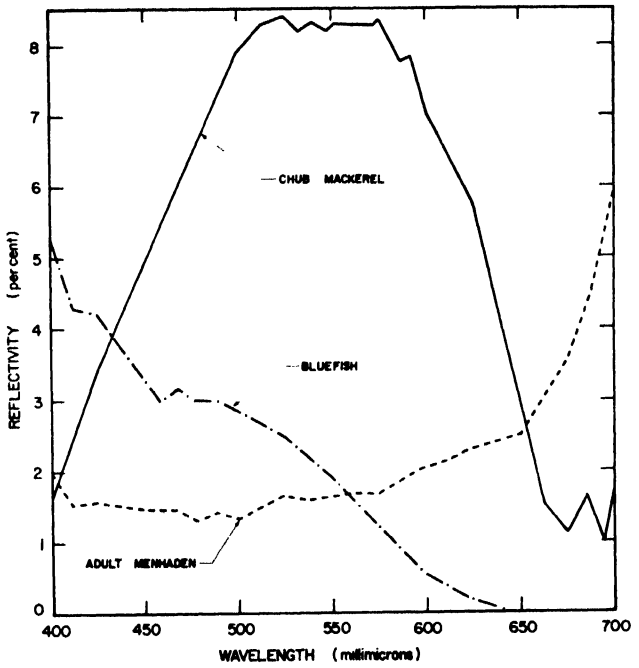

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PROBLEM OF NIGHT ASSESSMENT

Night-time detection of fish schools is also being investigated at Pascagoula Base. Image intensifiers coupled to a closed circuit television system detect bioluminescence associated with fish schools (fig 3). Commercial fishermen

Fig 3. Low-light-level sensor and video components used to detect and record bioluminescence

have used "fire" (bioluminescence) in the water to detect and catch fish for many years. This fire is created by the movement of fish which cause luminescent organisms to glow. A study has been initiated to determine what organisms cause the luminescent flashes and their relative and absolute abundance.

The image intensifiers used in our studies have ranged from small scopes similar to those used by the military services to a system specially designed for use aboard aircraft. The various units all work on the principle of amplifying ambient light and the most powerful we used has approached 100,000 times intensification.

Observations were made with the low-light-level systems to detect bioluminescence associated with artificial targets and also with SCUBA divers, individual fishes, and fish schools (figs 4 and 5).

Fig 4. Individual fish outlined by bioluminescence

Fig 5. Fish school outlined by bioluminescence

These preliminary tests suggest that low-light-level sensors may be used effectively from high altitude for locating and possibly identifying pelagic fish schools over large oceanic areas.

FUTURE PLANS

Future research plans at Pascagoula include further investigation into the various potential sensors and techniques for assessing pelagic fish schools as well as new sensors and techniques. Two new sensors being considered are lasers and multispectral scanners. Much attention is being given to selecting a platform to test and evaluate remote sensing instrumentation and techniques. Permission has been obtained from the United States Naval Ship Research and Development Center, Panama City, Florida, to utilize their offshore oceanographic Platform, Stage II (fig 6). The platform is about 80 ft high and is equipped with an automated

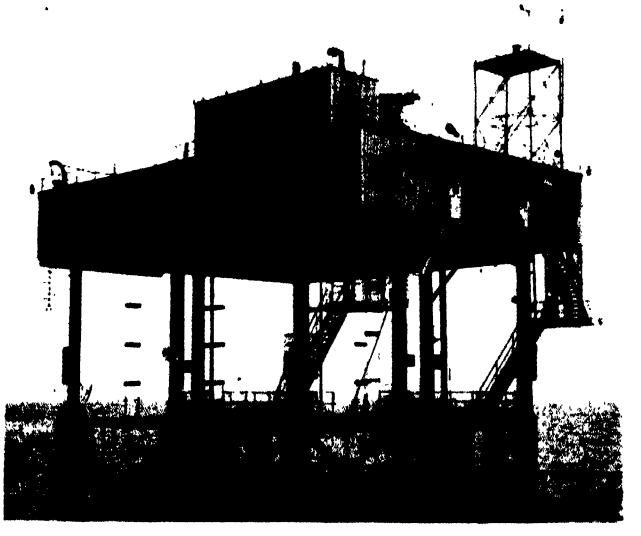

Fig 6. Naval Oceanographic Platform—Stage II

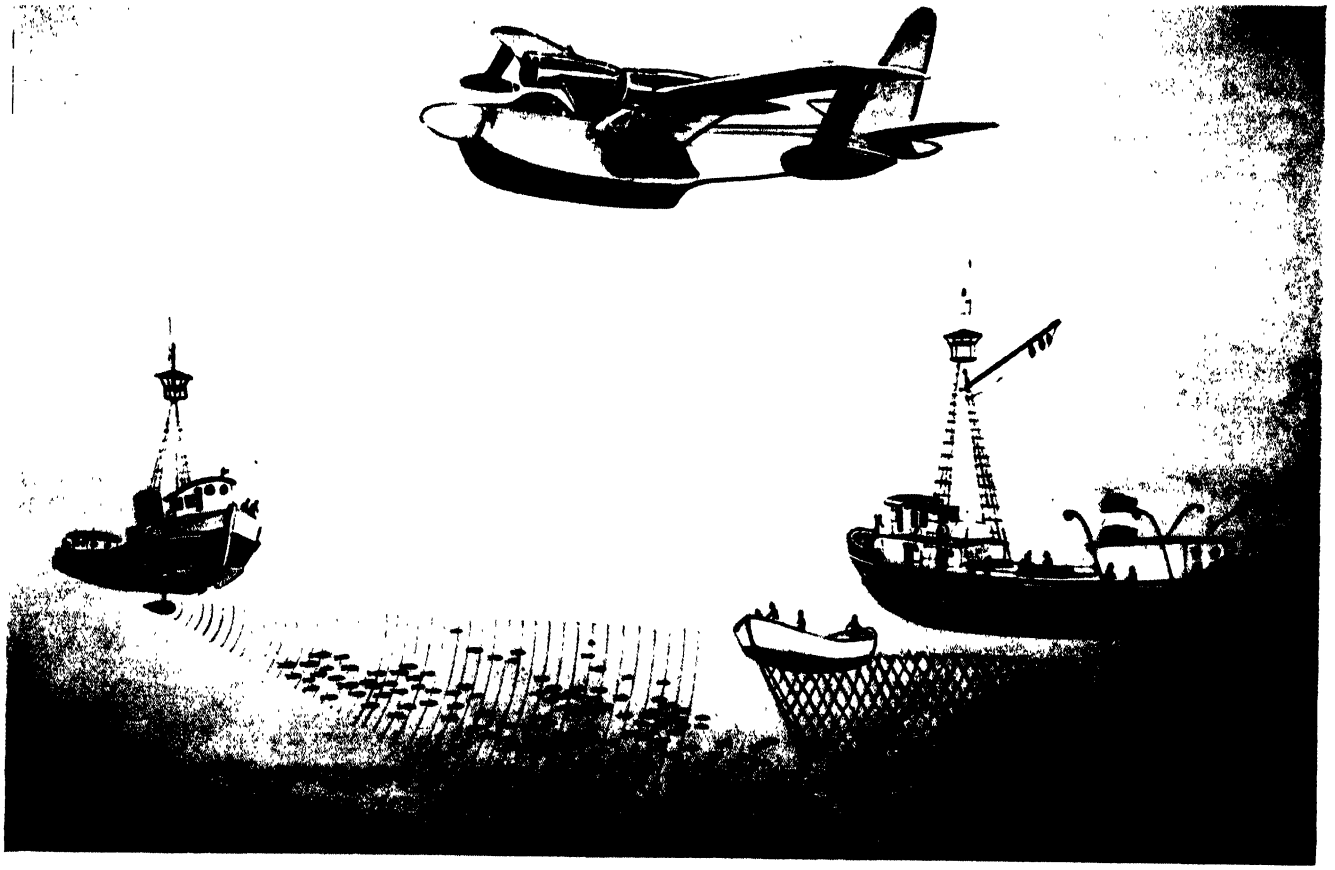

Fig 7. Artist's impression of fish detection and data dissemination from an aircraft

Fig 8. Artist's impression of fisheries remote sensing system from space

data acquisition and environmental monitoring system. The system records daily the following parameters once per second during three two-hour periods; wind speed and direction, air temperature, water temperature at 10 levels, wave height, and current speed and direction at two levels. The water conditions at Stage II are representative of coastal waters in the northern Gulf of Mexico.

CONCLUSION

From this research, the Bureau of Commercial Fisheries expects to develop a remote sensing system for daytime and night-time detection and assessment of pelagic fish stocks (figs 7 and 8). The system would give rapid, synoptic coverage of important fishing areas and provide real-time data on the location, quantity, and species of near-surface schooling fishes. Information obtained would be relayed to both industry and management for efficient utilization of pelagic fish stocks. We can expect more profits to industry and better consumer prices through increased production and efficiency. Management will have a tool to make systematic appraisals and predict availability of fishery resources and degree of utilization over the world's oceans.

Video Scallop Assessment System

by W. R. Seidel

Systeme visuel pour l'estimation quantitative des coquilles St. Jacques

Un système sous-marin pour l'estimation quantitative à distance d'une pêcherie (abb. RUFAS) a été construit par le Bureau des Pêches Commerciales. Son but principal est d'évaluer rapidement, par des moyens visuels, les concentrations relatives des gisements de Coquilles St. Jacques Calico sur des secteurs géographiques étendus. Le véhicule est un corps remorqué de caméras photographiques et de télévision. On emploie deux opérateurs; l'un pour contrôler le mouvement vertical et la stabilité du véhicule, l'autre pour vérifier l'information reçue. L'expérience, bien que limitée jusqu'à présent, suggère que la technique peut constituer un instrument valable pour obtenir une réduction marquée du temps de recherche non productif des navires commerciaux pratiquant cette pêche.

Evaluación televisiva de los bancos de vieiras

La Oficina de Pesca Comercial ha elaborado un sistema para la evaluación de los recursos pesqueros submarinos profundos. Su objetivo principal es evaluar rápidamente, por medios visuales, las concentraciones relativas de los bancos de vieiras en vastas zonas geográficas. Se emplea para ello un aparato remolcado, dotado de cámara televisiva y fotográfica. Se utilizan dos operadors: uno para controlar el movimiento vertical y la estabilidad del vehículo y otro para registrar los datos recibidos. La limitada experiencia reunida hasta la fecha indica que esa técnica puede ser valiosa, porque permite reducir notablemente el tiempo improductivo que las naves comerciales dedicadas a esta pesquería emplean en la localización de los bancos.

A SIGNIFICANT advance has recently been made which allows rapid location and evaluation of calico scallop beds. Scientists of the Bureau of Commercial Fisheries, Exploratory Fishing and Gear Research Base, Pascagoula, Mississippi have constructed and successfully field tested a remote controlled, underwater vehicle called RUFAS (remote underwater fishery assessment system). The towed sled (fig 1) is vane controlled and senses roll, pitch and height above bottom, which allows an operator aboard the towing vessel to position the sled at any desired altitude above the sea bed. Underwater lights, a motion picture camera and a TV camera with video tape recorder allow rapid and accurate estimation of calico scallop concentrations.

The need for such a system became apparent while trying to assess the Cape Kennedy calico scallop beds discovered by the Bureau a few years ago. The traditional approach of sampling by dredging provided valuable information but left many unanswered questions. Many times a dredge would be filled to capacity while the very next drag would produce no scallops. Unknowns such as distribution ("patches"), orientation of beds, mobility, year-to-year variations and many others could not be satisfactorily answered by dredging. Solutions to these

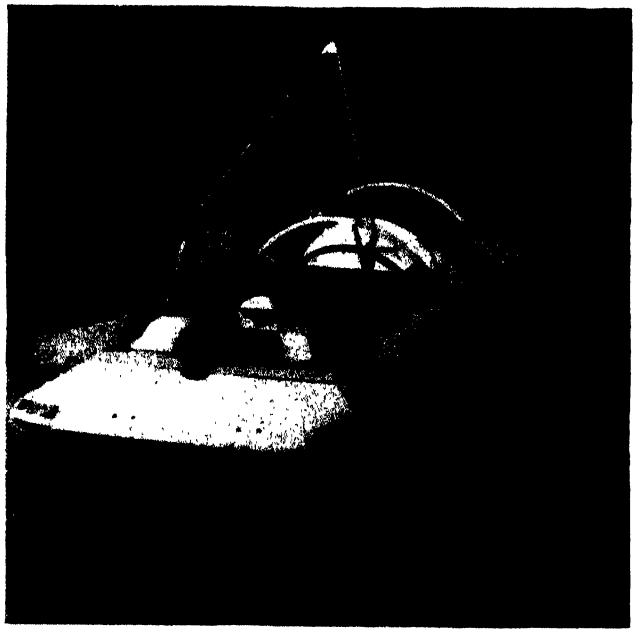

Fig 1. RUFAS—underwater vehicle of the system

problems could greatly assist the commercial fisherman in efficiently harvesting the scallops and visual evaluation was considered an excellent solution.

BCF personnel conceived and developed the controlled sled concept. To expedite construction, assistance was requested of the General Electric Company, Management and Technical Services Department, Bay St. Louis, Mississippi. A joint effort was initiated in February 1969. Completion was set for 30 June, in time to conduct a summer scallop survey.

SYSTEM DESCRIPTION

The system was designed for surveying the scallop beds off Cape Kennedy, Florida. Water clarity here varies considerably, but if the sled was manoeuvrable to within 5 to 7 ft of the bottom, data could be obtained except in turbid water. To accomplish near-bottom operation, the following specifications were established:

1. Towing speed—1 to 5 kn.
2. Operational depth—0 to 300 ft.
3. Manoeuvrability specifications:
   (a) Operational 5 ft above bottom (±1 ft).
   (b) Dive rate—1 ft per sec, maximum.
   (c) Ascent rate—4 ft per sec, minimum.
   (d) Obstacle clearance—50 ft object in minimum of 15 sec.
   (e) Lateral range—none required.
4. Roll, pitch and yaw stability adequate for optimum photo and TV observations.

To properly control the vehicle, certain information had to be available to the operator. General control required that he always be aware of the vehicle's roll and pitch. Since he would be manoeuvring the sled with two vanes, the operator also had to know the angle of each vane to maintain proper balance. These parameters, combined with a measurement of the height above bottom, would enable the operator to manoeuvre the vehicle vertically.

A vertical sounder aboard the towing vessel provided obstacle warning. At a normal towing speed of 2 kn there is a travel interval of about 1 min, depending on cable length, between the towing vessel and the sled. Therefore, if an obstacle appeared on the tow vessel's vertical sounder, the operator had ample time to manoeuvre the sled over it.

SYSTEM DEVELOPMENT

Design was initiated with a basic sled-frame developed by the Bureau several years earlier for another application. However, it was necessary to conduct a model study on the sled's dynamics to determine the optimal location for the control vanes.

A 1 : 10 scale model was constructed and tests were conducted at the General Electric facility, Bay St. Louis, Mississippi. Primary emphasis in the scale reduction was given to maintaining a geometrical accuracy. Tow tests were conducted in a 5,000-gal (US) tank 15 ft in diameter and 4 ft deep. The model was towed behind a revolving arm suspended a few inches above the water surface. A constant tow radius was always maintained. Two test speeds of 1.07 ft per sec and 2.67 ft per sec were used, based on the Froude number technique, to represent a full scale sled speed of 2 and 5 kn.

It was found that the most desirable location for the control vanes was at the rear of the body, but only when coupled with two fixed-angle vanes forward. Maximum effectiveness of the control vanes was between zero and 15°. Locations for the rear control vanes and the forward static vanes were determined. Best stability and performance was accomplished when the pitch axis, centre of buoyancy, and centre of gravity were aligned in a common vertical plane.

The major obstacle to the short design and fabrication was the instrument cable for power and control. Preliminary design showed that a 28-conductor cable with shielding and two coaxial conductors would be required. Armoured cable was ruled out because the winch drums aboard the towing vessel were too small to handle 1½-in diameter cable. Therefore, a 1-in diameter neoprene coated instrument cable was custom built. It was stored on a separate reel and attached with quick release hooks to the $\frac{5}{16}$-in stainless steel towing wire during deployment of the sled. In this way the two cables were held together and prevented torque on the sled.

A custom-built 200 kHz vertical sounder was used to provide height above the bottom. A dual range system provided depth from 0 to 100 fm in 1 fm increments and from 0 to 40 ft in 1 ft increments. Distance was interpretable to 3 in on the short range scale.

Hardware for the system

To provide photographic and TV capabilities, an underwater TV camera and monitor, a 16 mm motion picture camera, three 500-W quartz iodide lights, and a video tape recorder were acquired. Consoles including power supplies and sequence timing circuitry, were built to control and monitor the visual equipment. The main control console, from which the sled was manoeuvred, was also assembled.

Hardware which had to be designed and constructed for the vehicle consisted of a tow-bar and yoke, two underwater housings to enclose control circuitry, motors, sensors, TV tilt mechanism, control vanes, flotation tanks, and mounting hardware. It was decided during early design to maintain a positive vehicle buoyancy of about 100 lb. This was to provide some margin of safety because of the near-bottom travel requirement In the event of sudden impact with the bottom, the vehicle would always tend to rise.

FIELD EVALUATION

Several trials were conducted in the Pascagoula area prior to the first scallop survey. During these tests, system performance was evaluated and operators were trained. To maintain near-bottom position over varying depths and irregularities, the operator had to develop handling confidence and familiarity with vehicle response.

In early tests, sled stability when awash at the surface, presented a problem. To correct this the two vertical

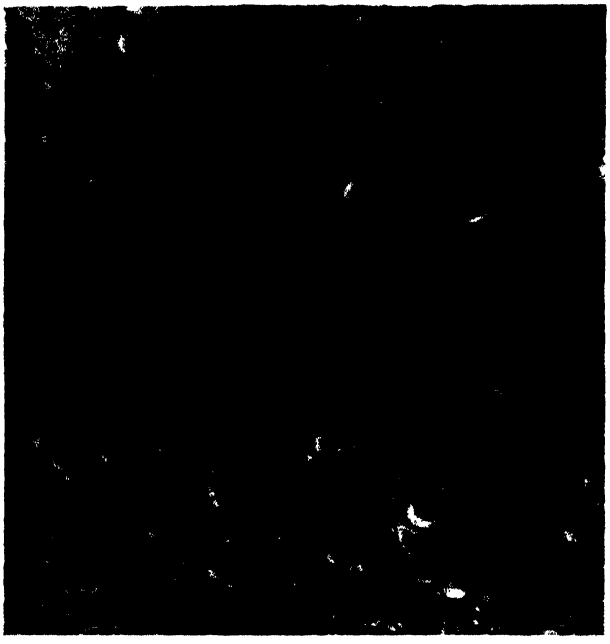

Fig 2. Example of a light scallop concentration on the Cape Kennedy scallop grounds

runners on the bottom of the sled were panelled to act as vertical stabilizers. Also, tow yoke location, optimum angle of the static vanes and tow cable tensions were determined for optimum vehicle performance.

Following at-sea checkout and operator training, RUFAS was taken to Cape Kennedy for a scallop survey. Objectives were to determine areas in the system which needed improvement and to provide information about the scallop grounds for use in planning future surveys. Thirteen transects were established which covered the known scallop grounds. Each transect followed a major East-West loran line of position from the 15- to the 25-fm curve.

During each transect, two men were used to operate the system. The operator was responsible for manoeuvring the sled and the data recorder watched the TV monitor, made reference checks for the video tape and periodically recorded the vehicle height above the bottom. When scallops appeared, the data recorder turned on the motion picture camera and noted the position in the transect. In this way film was conserved by only photographing areas which contained scallops. Seven of the 13 transects were completed before a hurricane terminated the cruise.

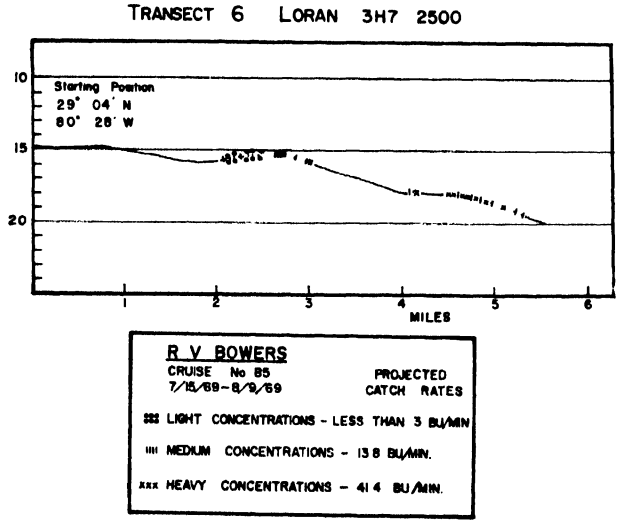

Fig 3. Results from a single transect, as prepared for distribution to the scallop industry. Heavy scallop concentrations are at 18–19 fathoms, sand dollars predominate at 15–15.5 fathoms, while above 18 fathoms concentrations are patchy

RESULTS CONSIDERED

During the seven completed transects, 70 mi of scallop grounds were covered and about 4,400 ft of movie film at 4 frames per sec were exposed. Continuous video tape monitoring was attempted but not accomplished because of synchronization problems between the TV camera and the video tape recorder.

The information obtained was classified into three scallop concentration levels described as light, medium, and heavy. Light concentrations were defined as 15 per cent or less of a film frame filled by scallops. Medium concentrations were 15 to 50 per cent and heavy concentrations were 50 per cent or more. Figure 2 shows a light scallop concentration. By combining the density level per frame with the number of frames of each density level, the amount of scallops in the path covered by RUFAS was determined. Finally, using an average size per scallop and assuming a 100 per cent efficient dredge (8 ft width towed at 3 kn), a projected catch rate could be made. Data obtained was plotted in graphic form as shown in fig 3. This information was given to the commercial fishing vessel *Sylvia Mae* and by concentrating efforts in the high density areas, in 20 fishing hours, was able to take 1,200 bu (US) (the vessel's capacity). This represented an ex-vessel value of $2,400. Thus the value of providing near real time information on stock density was amply demonstrated.

Some minor but easily corrected system deficiencies were found during the survey. Inadequate lighting for the TV camera must be rectified. Average towing speed of the sled was about 3.5 kn, which is somewhat high and should be reduced if possible during future surveys. However, from both an engineering and operational viewpoint, RUFAS proved that it can perform the mission it was designed to do. Near bottom travel was possible in calm to moderate seas and over rough terrain it was tedious, but not unduly so. Most important, the film recordings of scallops demonstrated that it is now possible to assist the commercial fisherman by providing information on resource availability in a way never before possible.

Practical Applications and Limitations in the Method of Fish Finding by Passive Listening

G. Freytag

Applications et limitations pratiques de la methode de detection du poisson par ecoute passive

La valeur de la méthode de détection du poisson par écoute passive est limitée par les interférences dues aux bruits d'ambiance, de navires et d'engins. L'auteur présente des calculs qui indiquent l'influence de ces bruits parasites sur la perception des bruits d'animaux sous/marins. Il fait mention de certaines sources pouissantes de sons sous-marins qui permettent d'influer sur le comportement du poisson.

Aplicaciones practicas y limitaciones del metodo de localización de los peces por escucha pasiva

La importancia de la localización del pescado mediante escucha pasiva se ve limitada por las interferencias debidas al ambiente, la embarcación y el ruido del equipo. Se presentan algunos cálculos que muestran la influencia de esos ruidos parásitos en la percepción de los sonidos emitidos por los animales bajo el agua. Se mencionan algunos emisores potentes de sonidos submarinos que permiten influier en el comportamiento de los peces.

MARINE crustaceans, fishes and mammals have a variety of different sound producing mechanisms, and sound pressure and frequency composition vary on a large scale (Table 1). Since most animal underwater noise observations have been recorded in tanks or in shallow water areas of small size or depth as compared with wavelengths it can be assumed that the sound pressure figures given are somewhat too low, especially in the low-frequency range (Freytag, 1967). The sound pressure of fish noises ranges from 27 to 34 dB re 1 μb. Under the assumption of spherical distribution of the sound waves and absence of any parasitic noise, the sound of this energy will travel under water over a distance of 50 to 70 m.

TABLE 1. SOUND PRESSURE OF ANIMAL UNDERWATER NOISE

	RMS sound pressure in dB re 1 μb	*Frequency range Hz*	*Distance from hydrophon (m)*	*Mechanisms involved*
Atlantic cod *Gadus morhua*	31–33	40–800	2	swimbladder
Haddock *Melanogrammus aeglefinus*	30–32	20–20,000	0.3	swimbladder
Horsemackerel *Trachurus tr.*	27	150–1,500	0.5	teeth grinding
Gurnard *Trigla gurnardus*	33	40–1,000	1	swimbladder
Wolffish *Anarhichas lupus*	24–28	40–9,000	0.5	feeding
Herring *Clupea harengus*	−6	1,000–7,000	?	swimming
Toadfish *Opsanus tau*	34	40–1,000	2	swimbladder
Spiny lobster	−10 to +9	100–5,000	1	mechanical
Crabs *Portunus, Carcinus* spec.	4–6	40–10,000	5	mechanical
Harbour porpoise *Phocaena ph.*	36	40–10,000	4	echo pulse

NOISE INTERFERENCE

Ambient noise

Wenz (1962) concludes that, in general, the ambient noise is composed of at least three overlapping components: turbulent-pressure fluctuations, range 1 to 100 Hz; wind-dependent noise (bubbles and spray) primarily due to surface agitation, range 50 Hz to 20 kHz; and in many areas, ship noise, range 10 to 1000 Hz. Long-range ambient noise measurements show a fluctuation in noise level in the order of 40 dB (e.g. fig 1, Chalfant and Buck, 1968).

The error in measuring animal underwater noise is given by the so-called signal-to-noise ratio. At a S/N-ratio greater than 15 dB the error in measurement tends towards 0 dB (fig 2).

The transmission loss may be considered to be the sum of the loss due to distribution and the loss due to attenuation. While distribution loss is a geometrical effect, the attenuation loss is a complex of at least three effects. In the frequency range of bio-sound (below about 5 kHz) the attenuation measured at sea is much higher than that given by theory. One cause is the absorption due to ionic relaxation of the magnesium sulfate molecules in seawater. In the frequency range between 5 and 50 kHz the absorption in seawater was found to be some 30 times that in distilled water. But at frequencies below 5 kHz there exists an additional cause of loss, the nature of which is not quite clear yet.

To give an idea of the masking effect of ambient noise,

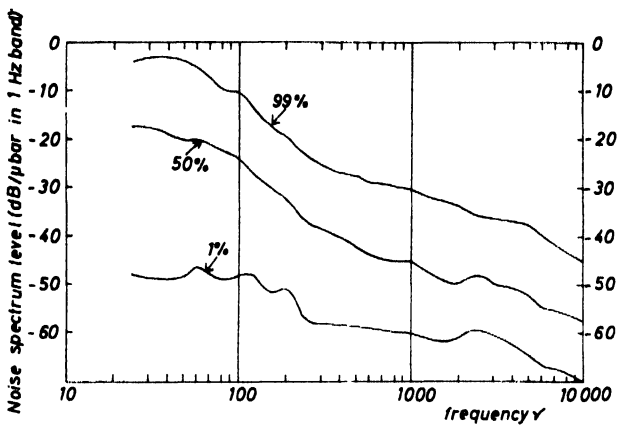

Fig 1. Variations given in the 99, 50 (median) and 1 percentiles in monthly ambient noise characteristics (May 1967, 355 samples) in the Santa Cruz Basin, west off Los Angeles. (Chalfont and Buck, 1968)

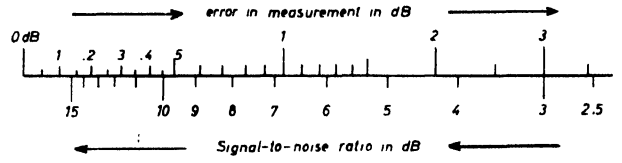

Fig 2. Relation between signal-to-noise ratio and error in measurement

fig 3 shows the range in which a 50 Hz signal, assuming spherical distribution, is 10, 20 and 30 dB above the median spectrum level of the ambient noise. Calculated for a bandwidth of 1 Hz, the SL-figure on the ordinate must be reduced according to the bandwidth of the analysing instrument ($\frac{1}{3}$ octave; octave).

At a sound pressure of +60 dB re 1 μb (at 1 yd distance from the source) the signal is 30 dB above median spectrum level of ambient noise in a distance of 560 yd, 20 dB above at 1,180 yd and 10 dB at 5,600 yd. Calculated for the $\frac{1}{3}$ octave with the centre frequency of 50 Hz the SL-figures on the ordinate have to be reduced by the bandwidth correction for this filter: −10.7 dB. Consequently at 60 dB sound source level the value of 30 dB above median noise is given at 180 yd, 20 dB at 560 yd and 10 dB at 1,800 yd.

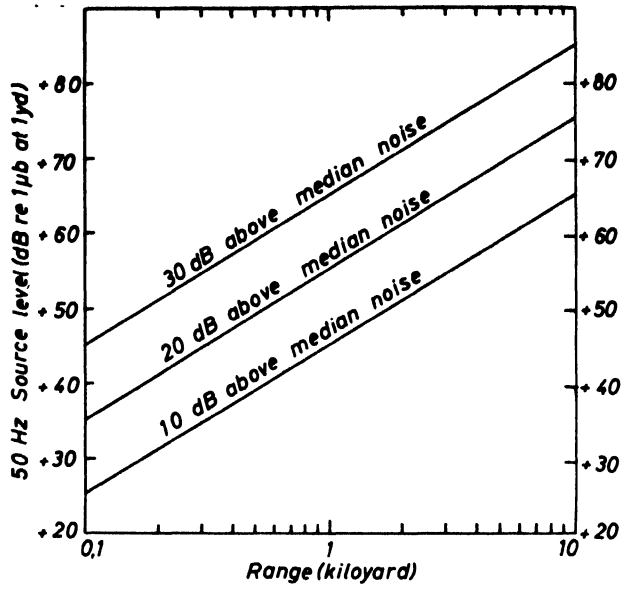

Fig 3. Range in which the signal from a narrow band 50 Hz source is 10, 20 and 30 dB above median spectrum level of ambient noise

The human ear as a detector and analyser of tonal signals in noise backgrounds is a remarkably efficient device. This efficiency has to be considered under the aspects of the analytical and integrative capacity of the ear: critical bandwidth and detectability of short-time transients (Zwicker and Feldtkeller, 1967).

Vessel noise

According to fig 3 a 50 Hz sound from a source with a pressure level of 33 dB re 1 μb (at 1 yd distance) is at a distance of 0.1 kiloyard 20 dB above the median spectrum level of the ambient noise. As compared with these figures, measured in a rather quiet area, fishing vessels produce a broad-band noise which at a distance of 50 m has a sound pressure of 30 to 50 dB re 1 μb (Table 2).

This shows clearly that presence of one fishing vessel would prevent or seriously hamper the practical application of passive listening for fish detection. On fishing grounds the underwater noise produced by several fishing vessels shows a logarithmic increment in pressure.

TABLE 2. SOUND PRESSURE CREATED BY DIFFERENT BOATS

	dB re 1 μb	*RPM*	*hp*	*BRT*	*Lo, m*	*Distance m*
CUTTERS (trawler)						
Lome (steel)	39	1600	294	93	22.5	50
Wega (wood)	30	1600	240	27	16.5	50
Werner (wood)	34	700	150	27	16	50
PURSE SEINERS*						
Boat No. 1 (circling)	34	310				50
Boat No. 2 (circling)	39	375				50
STEAMERS						
Anton Dohrn (full speed)	46	115	850	999	62	50
Fritz Homann (trawling)	53		2100	1319		70

*Measurements made by W. Röpert (1968).

Measurements in the herring fishing area off Northshields from 25 April to 4 September 1963 revealed a sound pressure at several locations between 20 and 32 dB re 1 μb in the frequency range from 40 Hz to 5 kHz produced by at least 160 fishing vessels, approximately 100 of which could be counted at a medium range of vision.

Ship noise is a typical broad-band noise, covering the whole range from a few Hertz (natural vibration of the ship) up to 10 kHz and more (propeller induced noise). The mathematical conversion to spectrum level covers the existence of strong spectral lines (single frequencies), especially in the region below 50 Hz (e.g. ignition frequency).

Gear noise

The effect of trawling as compared with the underwater noise created at full sailing speed for the cutter *Lome* (fig 4) was measured in shallow water of 12 m depth.

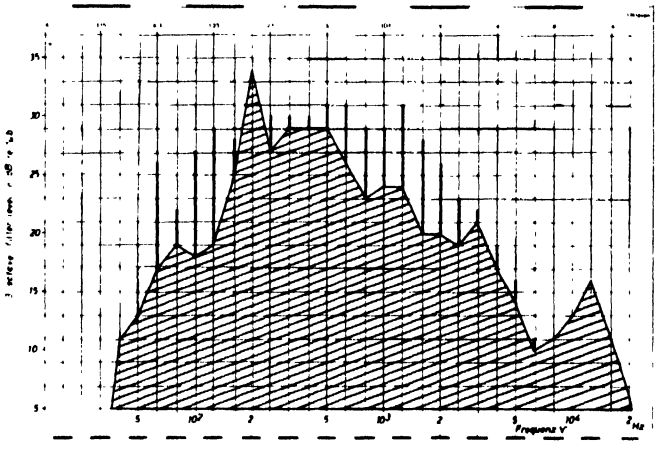

Fig 4. Cutter Lome: *comparison of spectograms; trawling noise and noise at full run (hatched). One-third octave levels*

Although this caused an alternation of the frequencies below 160 Hz, it can be seen that during trawling a more equalized broad band noise ($\frac{1}{3}$ octave levels in fig 4) is created as compared with free running at full speed. Especially in the region below 125 Hz the noise produced by the gear causes additive pressure in the range of 8 to 10 dB. In the upper frequency range the influence of the gear noise pertains to 2.000 to 3.000 Hz.

APPLICATIONS OF UNDERWATER NOISE

The possibilities of applying powerful sounds to influence fish behaviour are outlined by Chapman and Hawkins (1967) and Alverson (1968). However, the development of an underwater sound source, capable of producing a sound pressure of 80 to 120 dB re 1 μb (at 1 yd distance) in the low frequency range would be rather expensive. Thus one should first look for powerful instruments on the market, e.g. for seismic and hydroacoustic research.

Because of the high parasitic noise level created by ships and towed gears large-scale experiments of influencing fish behaviour would need much more energy than the tests which were performed in the limited soundfields in aquaria or small tanks. In most of these small-scale experiments electromagnetic loudspeakers were used which had an output of 30 to 50 W. Besides this disadvantage of too small energy (Type 'J 9' produced a sound pressure of 50 dB re 1 μb at 1 yd distance) these instruments were restricted regarding depths. A new type of "Hydrosounder" was constructed in recent years which has an energy input of 1 KVA. This electromagnetic system produces a sound pressure of 70 dB re 1 μb in the frequency range from 10 to 500 Hz, is pressure equilibrated and can be used to depths of about 70 m. Its weight (in water) is about 200 kg.

Magnetostrictive transducers are used in the frequency range from about 3 kHz to 200 kHz, but are not suitable for transmitting powerful low-frequency sound.

Unilateral bender transducers are available with outputs between 120 and 250 W for pulsed signals. Based on a rated output of 250 W the sound pressure in a distance of 1 yd can be expected to 85 dB re 1 μb. In the frequency range of some hundred Hz the loudspeaker acts omnidirectional. For increase in directivity five of these sounders can be mounted in $\lambda/2$ distance in a row.

The calculation for this arrangement is:

1 × 250 W	85 dB/1 μb
5 × 250 W	92 dB/1 μb
Gain by directivity	14 dB/1 μb
	106 dB/1 μb

The **boomer** consists of two plates which are driven by a central coil. The energy output is rather low, approximately 1.000 Joule. This instrument is used in research in surface regions.

The **airgun** has a frequency spectrum from below 100 Hz up to 2 kHz. The power output ranges between 10 to 20,000 Joule respectively 100 to 200 g TNT. This pneumatic sound source produces at a chamber volume of 150 cm^3 and 150 atm pressure a sound pressure of 115 dB re 1 μb at 1 yd and more powerful types are available. The airgun can be lowered to depths suitable for practical fishery.

Sparkers and **arcers** produce a noise of 3,000 to 25,000 Joule. The frequency spectrum is very broad with a maximum in the region of 2,000 to 3,000 Hz. But the short-duration pulses in the range of 1 ms and below are less effective for influencing fish behaviour. Airgun and sparker also produce considerable additional noise at depths of some hundred metres due to their airbubble release.

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DISCUSSION

FISH DETECTION

Visual Spotting of Fish

Sams (Chile) Rapporteur: In reviewing the papers on aerial spotting of fish schools, stressed the importance of the spotter having a good understanding of fishing and having experience of what goes on aboard the vessel to enable him to give realistic guidance to the captain in making a set. The captain must have absolute faith in the spotter.

Aerial spotting is mainly used in the USA menhaden fishery and to some extent in tuna purse seining, as well as in the Chilean anchovy fishery. From his experience as an aerial spotter in Chile he felt that these methods could be used effectively in many other pelagic fisheries, for instance in Peru.

Klima (USA): The reasons for developing the underwater video observation vehicle RUFUS were that calico scallops consist of a one-year class and their location varies from year to year. Consequently it is difficult for fishermen to find commercial concentrations. Visual assessment with RUFUS provides information on distribution and state of the stock and has a forecasting capability. This system can be used for surveying any bottom fauna where visibility is 3 metres or more. We are now developing another system capable of surveying down to 500 fathoms.

The emphasis is on locale of commercial concentrations, assessment of the resource, and providing information on stocks and forecasting, which is supplied to management, industry and fishermen on a daily and long-term basis.

Stevenson (USA): Both the menhaden and anchoveta fisheries are essentially daylight operations. An effective potential to improve harvesting efficiency is to extend the operation to 24 hours. There are however some successful night-time fisheries. When fish are in an area there is the possibility that bioluminescence will result from their activity.

The Pascagoula laboratory has been working on application of image intensifiers for locating fish under conditions of low light level, the instruments under development having sensitivity of up to a hundred thousand times greater than the human eye. When this has been developed it is hoped that resource surveys and fishing operations can be extended over the whole 24 hour period.

Menhaden (*Brevoortia species*), a highly important industrial fish, supports an extensive purse seine fishery along the US east coast and the Gulf of Mexico. The entire catch is made by vessels operating from factories located in 12 coastal states, and a fleet of carrier vessels ranging from about 65 to 200 feet and from about 50 to 700 gross tons, transports the catch to the reduction plants. These vessels carry the purse seine dories and fishing gear to the fishing grounds and provide living accommodation for fishermen. Many vessels in the Gulf of Mexico have a brine cooling system for preserving the catch which is stowed in a large central hold. Menhaden are caught with purse seines, two open seine boats being lashed together with the seine divided equally between them, and towed behind the carrier vessel.

Airplanes locate the fish, and direct the laying of the seine by radio communication to the fishing captain. In setting the seine, the two boats separate, and the seine is paid out as each boat completes a half-circle to enclose the school. The bottom of the seine is then closed, or "pursed", confining the fish. Power blocks haul in the ends and bottom of the seine until the fish are confined in the bunt, and the catch is then pumped into the hold of the carrier vessel. An average purse seine set yields from 20 to 25 tons of fish. The carrier vessels usually make daily trips and land catches after dark or when the hold has been filled.

Just after World War II several menhaden reduction companies initiated the use of small aircraft to assist in detecting fish schools. Some captains acquired pilots' licences and purchased aircraft for their own personal use in locating fish schools.

The basic technique used has not changed over the past 25 years. Fish are observed visually and sizes of schools are determined by discolorations in the water coupled with bird activity and the spotters' general knowledge of seasonal conditions such as weather, sea state, fish movement, etc.

Aircraft are used for scouting, spotting and fishing. **Scouting** is long-range fish detection by an aircraft having an airspeed of about 175 knots and a range of 200–500 nautical miles.

Twin Bonanzas or similar small 4 to 6 passenger executive type craft are typical examples. At about 20 miles from shore, the planes fly specific patterns over the range of the fishing vessels (100–200 nautical miles), the coastal area being covered in a grid pattern once a day. Scouting locates concentrations for determining operational plans on a daily and weekly basis, and the information is relayed to vessel captains in written form when they return to off-load the day's catch. Each company operates at least one scouting plane, which will provide information for 20–30 vessels primarily because of the corporate structure of the industry. Reduction in scouting costs would result if individual companies used one single source of fish concentration information. It is estimated to cost about $125,000 per year to operate aircraft of this type, but return per ton of fish caught is difficult to establish because of multiple utilization of these aircraft by companies.

Fish spotters are small single-engined aircraft with an airspeed of about 45–90 knots modified to extend their range to about six hours' flying time. Spotter planes which each service 3 to 5 purse seiners, are, at dawn, on the fishing grounds indicated by the report from the scouting pilot of the day before. As schools are located, the nearest available vessel, owned by the same company as the aircraft, is advised by radio, but often competitors are on to the school first, and current fishing procedure dictates that the first vessel to set a net around the school is owner of the school. Each vessel monitors the UHF radio frequencies of competitors and it is not unusual to have several vessels and spotter planes actively competing for the same school.

Once upon the school, if the captain decides to set, he notifies the spotter, who assists in encircling the fish. Communications are maintained between the spotter pilot and the vessel by UHF and FM radio.

Considerable confusion exists in the air column above a large concentration of 50 to 60 vessels fishing in the same area. Several aerial collisions have occurred and about 5 pilots have been lost over the past twenty years. To minimize the danger and provide for orderly operations, a procedure allocating specific air patterns and flight elevations has been developed and put into effect. In the North Carolina winter fishery, fish scouting and spotting inter-company consolidation was initiated in the past five years.

Operational costs of spotter planes are estimated at about $14,000 per year including pilot. Pilots generally own their planes and contract to a specific company for the entire season. Costs of fish spotting are estimated to range from $1.25 to $2.50 per ton of fish depending upon the area of operations and availability of pilots and maintenance crews.

Because of the industry organization, little change in procedures for use of aircraft is expected over the next five to ten years. Developments of instruments and sensors to locate menhaden schools at night could extend the operations from 12–16 hours per day to 24 hours within 10 years. Success of extending the operational day will depend upon crew acceptance of night fishing and adoption of single boat seining techniques as well as night detection capability.

Green (USA): An aerial spotting service has been extensively used in the tuna fishery in California. The aircraft are shore-based and this has proved to be more efficient than using ship-based aircraft. An aircraft serves several vessels and receives revenue as a percentage of the gross catch.

Ben Yami (Israel): While aerial fish spotting can only pay in relatively rich fisheries, occasional or periodic aerial scouting might pay also in a fishery for small schools, by informing the fleet as to areas of fish concentrations and thereby saving seatime otherwise spent searching.

McNeeley (USA): There is evidence that by passive listening in a wide band form, about 0–100 kHz, noises of biological origin can be detected. Often, however, they are masked by ambient sea noise and noises produced by the vessel. Let us, however, not stop developing this technique too quickly as valuable information may be gathered in this way.

Midttun (Norway): Whales produce noises which are picked up strongly through the transducers of sonar sets, and can be followed in this way. I think that something could be done with passive listening to noises produced by whales.

Gronningsaeter (Norway): Just after the second World War the newest passive acoustic equipment captured from the enemy was used to listen to whales. We were able to detect when the mink-whale was preparing to surface, as gurgling noises were produced. Our range of detection was up to 1000 yards. However, the industry was not very much interested and the device was not further developed due to the decline of the whaling industry.

v. **Brandt** (Germany): The idea of using passive detection methods originates from South East Asia. At present a large amount of records of underwater noises have been collected, but the difficulty is to ascertain where the noises come from. Experiments are made in tanks and aquaria but the noises obtained in this way differ widely from those recorded in the open sea. I do not see much future hope for this technique of detecting fish.

McNeeley (USA): I agree that it is difficult to determine and distinguish noises produced by fishes, but I would like to point out that crustaceae (shrimp) produce noises at approximately 5 kHz making detection easy. However, ambient sea noise limits the range. I would like to say that the detection of fish noises is difficult but further research in this field is necessary.

Echo Sounding—Present Status

R. E. Craig

Echo Sondage—Situation Actuelle

La plupart des techniques qui semblent encore nouvelles et importantes ont été décrites ou prévues en 1957, à Hambourg, lors du premier congrès FAO des engins. Par suite de la division des efforts entre de petits groupes dans des pays différents, le développement de l'écho sondage à l'échelle mondiale a été d'une lenteur décevante Le deuxième congrès, en 1963, montra un certain développement de l'équipement et de l'utilisation, mais avec seulement use idée fondamentalement nouvelle. A l'heure actuelle en 1970, nous ne pouvons encore signaler qu'une seule invention vraiment nouvelle (le style en peigne), le progrès principal ayant été observé au niveau de la recherche dans l'amélioration de la précision quantitative de notre équipement et de nos méthodes. Ces méthodes influenceront vraisemblablement l'équipement de pêche commercial dans un proche avenir et le temps est venu pour le patron désireux de progrès de commencer à penser aux résultats quantitatifs. Introduction à ce problème, les fonctions de gain à variation dans le temps (abb: TVG) sont examinées. En conclusion, une vue personnelle est présentée sur les améliorations qui interviendront probablement dans la pêche commerciale au cours des toutes prochaines années.

Sondeo Acustico—Situación Actual

Muchas de las técnicas que aún hoy parecen nuevas e importantes fueron ya descritas o anunciadas en 1957, con ocasión del primer Congreso de Artes de Pesca de la FAO celebrado en Hamburgo. A causa de la fragmentación de los esfuerzos entre pequeños grupos de varios países, los progresos a escala mundial del sondeo acústico han sido enormemente lentos. En el segundo Congreso de Artes de Pesca, celebrado en 1963, se observaron algunos progresos en lo relativo a equipo y manipulación, pero sólo se presentó una idea nueva fundamental. También en 1970 hemos de limitarnos a reseñar una invención realmente nueva (la aguja de peine), mientras los principales progresos se han registrado en el plano de la investigación y han consistido en una mejora de la precisión cuantitativa de nuestro equipo y nuestros métodos. Con toda probabilidad, estos métodos influirán en el equipo de pesca comercial del próximo futuro y ha llegado el momento de que los capitanes modernos empiecen a pensar en los resultados cuantitativos. Como introducción a esta cuestión, se examina el problema de las funciones de ganancia de amplificación según el recorrido de la señal. Para concluir se da una opinión personal sobre los progresos más probables en el sector de la pesca comercial en los próximos años.

AT its gear congresses, FAO's Department of Fisheries has brought together the most comprehensive expertise in fish detection. Through its attractive publication of proceedings, FAO has been also the most important disseminator of information on the subject. The various field projects of FAO have provided a powerful stimulus to quantify echo sounding results, and to make these results comparable on a world-wide basis.

It is therefore of interest to look back on earlier gear congresses to determine what progress, if any, there has been in the past decade.

THE PAST CONTRIBUTIONS

Looking first at the Hamburg congress in 1957, we find that a scientific appreciation of echo sounding requirements and potentialities was already widespread, at least among fishery scientists. Papers discussed the need for narrow acoustic beams, and higher frequencies to give improved resolution—in practice to give more detail of bottom contours, to give more power to find fish close to the seabed, and more power to count fish individually.

We find also, particularly in Japanese papers, a strong awareness of the need to know more about sound transmission in the sea, and about the target strength of fish at various frequencies. A number of papers gave preliminary estimates of the attentuation coefficient of sound in the sea in both the vertical and horizontal direction, and measures of the target strength of various fishes. The "target strength", as it is now known in the West, was described in these papers under the equivalent terms of "reflection loss". (Strictly a target strength of say −30 db corresponds to a reflection loss of 30 db).

Thus we see Japan giving a lead in the fundamental physics of the subject. The Western countries, particularly the United Kingdom and Germany, were reporting the technique of netsonde, which in the latter country has become highly developed because of the special needs of a major midwater trawling industry. Manufacturers recognized the special value of paper recording, but were striving to overcome some of its deficiencies by special techniques such as "white line" and "grey-black" recording. These have been appreciated and widely adopted as useful refinements of display.

From Western shores of United States we had reports of the practicability of trawl warps with an electric core, for use with instrumented gear. Others have been slow to accept such methods, even for research, but the author is glad to say that his colleagues in Aberdeen have now adopted this idea.

Available techniques for horizontal search were almost the same as at the present day, though of course much less widely used, and both Norway and Iceland had recognized the need for detailed study of the tactics of using such equipment, and for the training of operators.

At the second gear congress in London in 1963, the author as rapporteur on Fish Detection had to emphasize that many important papers were not submitted for the fish detection section, but occurred in other sections under the purse seining and pelagic trawling. In other words the techniques of horizontal sonar, and of netsonde had become wholly absorbed into fishing techniques and gear research. Also again the need for training in using these powerful fishing tools was emphasized.

There were two new ideas in technique, both incorporated in papers from the United Kingdom: the introduction of a bottom lock recorder, again a display refinement, and a forward-looking paper on Sector Scanning Sonar. This latter development is important but has not developed as quickly as might have been hoped. It was however fundamental, and was a first sight of the possibilities that lie ahead, when improved signal processing allows the extraction of all possible information from returning echoes. The principal technical paper from Norway on that occasion referred to calibration of source levels, and receiver amplification, to allow expression of the target strengths observed in

absolute terms and, in particular, ends with the proposal to introduce automatic fish counting as an adjunct to such a calibrated system.

THE PRESENT POSITION

The attempt to review developments since 1963 is not easy since this very congress will probably prove the first chance to review the field again. It is not expected that progress will be found satisfactory, considering the promise of a decade ago. Fragmentation of the study of this subject into small separate groups of workers each in most cases too small to achieve all that might be achieved, has resulted in a rather slow rate of progress.

In purely technical matters there seems to be only one significant innovation, i.e. from Japan. This is again a display refinement, being the introduction of the "comb" stylus for recording. By utilizing integrated-circuit techniques it is possible to time the echoes and feed them to that tooth of the comb which corresponds to the depth. Thus the familiar moving stylus can be done away with. The merits of the technique are that the time-base speed can be varied at will, and such features as bottom lock and scale expansion can be provided with flexibility, ease and reliability.

The Steered Narrow Beam echo sounder, developed in the United Kingdom is also worthy of note, being the first commercial application of electronic stabilising of the acoustic beam. A number of firms in several countries are able to supply stabilized transducer mountings on a regular commercial basis.

Then there is some improvement in equipment, of the nature of development rather than invention. A good example is "wireless netsonde", linked to the ship by a secondary (FM) acoustic link.

Again in the category of improvements, but this time in an aspect of far more fundamental importance is the realization commercially of the user's need for calibration, of the need for stability of power output and amplifier gain, and for the provision of suitable TVG or **time varied gain** (see below). At least one manufacturer is prepared to offer a choice of known and accurate TVG characteristics at the flick of a switch, while evidence suggests that some other manufacturers are aware of the need for this precision, though they do not feature it in their advertising.

Time varied gain

Any attempt to give a definite answer to the questions "Are these big fish or small?" or "Are there many fish or few?" depends on the estimation of the Size of the Returned Echo. Naturally enough a target will give a smaller echo if it is further away, that is if the range R is greater.

The simplest way of expressing this exactly is to say that **for single fish:**

$$E = S - 40 \text{ Log } R - 2RK + T + A$$

E = echo level in db
S = source level in db
RK = attenuation in db/m
T = target strength in db
A = receiver sensitivity in db

Now it will be obvious that if the electronics is so designed that:

$$A = \text{a constant} + 40 \text{ Log } R + 2RK$$

then the size of the received echo will be independent of the range and the presentation of the echo will be a fair indication of the size of the target. We would say that the TVG function of the equipment was **40 Log R + 2RK.** All this means is that the electronics has been designed to make the sensitivity of the receiver low at the moment of transmission, and to allow this sensitivity to rise smoothly at exactly the right rate to compensate for the increasing range.

The echo of the seabed or of a **large shoal** of fish does not obey the same rule, because as the range increases the acoustic beam becomes wider. The target being of large extent occupies the full beamwidth at all ranges and we have the different law:

$$E = S - 20 \text{ Log } R - 2RK + T + A$$

Thus the best TVG function in this case is **20 Log R + 2RK.** This difference between the echoes of widely dispersed targets and small single targets creates the greatest difficulty in quantifying echo sounding results, and is the main difficulty in providing commercial equipment to estimate quantities of fish in a simple way. The difficulties are not so great for scientists, who have time to assess their results carefully, and serious efforts are being made in a number of countries to get the answers right. A good deal of work of this kind is going on also in several of the FAO field stations. The problem of acoustic survey of new fishing grounds is a very challenging one.

Once these techniques are properly established by the research teams, it is likely that they will find their way into practical fishing. It will perhaps be understood that the problem is a little more difficult than can be fully treated here, but it is gradually being mastered.

FUTURE PROSPECTS

It is dangerous to pretend to see how developments will proceed in commercial equipment. As suggested above, the most important changes will be acceptance of a need for better calibration and the introduction of more quantitative equipment. It is also believed that we have only seen the beginning of the application of phase sampling or phase measurement techniques, which will be applied to echo sounding as well as to more general sonar, and will notably increase the reliability of our assessment of fish. In spite of the great success of netsonde with a cable link and associated complications the author believes that "wireless" equipment will in time be accepted as the best way of keeping in touch with fishing gear. It is assumed that though paper recorders will be used and maybe also cathode-ray tubes to give an immediate "picture" of what is happening, sophisticated electronics will gradually be adopted on the general pattern of modern computers, to give the fundamental quantitative information needed for planning fishing tactics. It is already obvious that such methods are acceptable.

Present Status of Echo Sounding and Sonar and their Application in Japanese Fisheries

M. Nishimura

Situation actuelle de l'echo-sondage et du sonar et leurs applications dans les pêches Japonaises

On trouve dans le commerce au Japon un large choix d'équipements d'écho-sondage et de sonar dans une gamme de 10 à 400 kHz Ils sont en usage dans plus de 70 pour cent des flottilles de pêche. Des études fondamentales, concernant la propagation acoustique, la réflexion, la déflexion, l'atténuation, la détection et le mode de présentation, sont effectuées depuis 1950. La plupart des recherches récentes comportent la mise au point d'un système acoustique de comptage des poissons. Des sondeurs à fréquence multiple ont été utilisés pour faire une discrimination entre les espèces de poissons, les éléments du plancton et du fond. Pour améliorer la définition à proximité du fond, le balayage rapide est maintenant possible grâce aux enregistreurs multi-styles possédant jusqu'à 300 styles balayés électroniquement. Les sonars japonais emploient le tube à rayons cathodiques (C.R.T.) ou la représentation sur papier en complément de l'indication acoustique. L'usage du sonar ne s'est pas encore généralisé dans les flottilles de pêche. L'expérience de l'auteur montre que cet appareil est de peu d'utilité pour la pêche du thon et que sa portée efficace en pêche est limitée à environ 1,000 m sur les bancs d'autres espèces. Pour la télémesure de la profondeur du chalut, on untilise à la fois des appareils acoustiques et dynamiques (pression de l'eau). Le système à "troisième câble" a été en général abandonné au profit de la transmission acoustique. Les systèmes les plus récents transmettent également des informations sur les performances du filet et sur les poissons dans le voisinage de celui-ci.

El sondeo acustico, el sonar y sus aplicaciones en las pesquerias Japonesas actuales

En el comercio del Japón se encuentra una amplia gama de aparatos de ecosondeo y sonar cuya potencia va de 10 kHz a 400 kHz. Los emplean más del 70 por ciento de las flotas de pesca. Desde 1950 se efectúan estudios fundamentales de la propagación, reflexión, desviación, atenuación, detección y presentación acústicas. Desde más recientemente se estudia un sistema para contar los peces acústicamente. Se han empleado sondadores de frecuencia múltiple para distinguir entre especies de peces, plancton y constitutivos del fondo. Para ampliar la definición cerca del fondo se practica en la actualidad la exploración rápida con registradores que tienen hasta 300 estiletes que se accionan electrónicamente. En los aparatos de sonar japoneses se emplean el tubo de rayos catódicos o las presentación gráficas, además de la acústica. En general las flotas pesqueras no han aceptado el sonar. La experiencia del autor indica que es de poca utilidad en la pesca del atún y que en el caso en que se pesquen otros cardúmenes su alcance es tan sólo de unos 1,000 m. En la telemetría de la profundidad del arte se emplean sensores dinámicos (presión del agua) y acústicos. En general, el sistema del tercer cable ha sido abandonado por preferirse la transmisión acústica. Los sistemas más modernos también envían información sobre la manera en que trabaja el arte y los peces que se encuentran en su vecindad.

FOR the past decade, echo sounders have been used widely in Japanese fishing operations. More than 70 per cent of fishing vessels over 10 m length have installed them for use in one or two boat trawling, purse seining, tuna longlining and miscellaneous hook and line fishing. They are used not only to detect fish but to obtain information about the oceanographic environment and biological behaviour of fish to make fishing operations easier.

Various echo sounders are available with a variety of frequencies, indication systems, types of transducers etc. The frequencies used range from 10 kHz to 400 kHz, and the frequency is selected according to the depth of fish to be detected, fish species and fishing methods.

FUNDAMENTAL PROBLEMS

Fundamental studies on propagation of underwater sound, reflections from fish, attenuation and generation of noise caused by bubble layers below the bottom of the boat have been in progress since 1950 by Hashimoto, Nishimura, Maniwa (1964), and their results have been detailed in many reports. Successive studies by other scientists to improve echo sounders and sonars are being conducted.

To obtain information on fish stocks, use of acoustics seems to be one of the more promising methods. In Japan, Nishimura (1969) developed an acoustic fish counting system in 1965, and successively, Nishimura, I. Yamanaka (1970), Shibata and Aoyama (1969), Ishii and Tanaka (1969) are now engaged in studies of the application of an automatic acoustic fish counting system under financial support of the Japanese Fisheries Agency.

Ultrasonic frequency in echo sounding

In Japan the frequency band has been extended from 10 kHz to 1 MHz depending on the depth of fish or purpose of fishing operation. In addition, twin or triple frequency echo sounders are used to discriminate fish and other unknown echo traces. For example, if fishermen have discovered a mixed echo trace of fish and scattering layer, they change frequency to confirm the existence of fish. They report that a change of frequency is effective to identify groups of prawns in trawl fishing. On the other hand, frequencies as high as 200 or 400 kHz are used to study the deep scattering layer, detect schools of shrimp and other small fish. Nishimura (1968) has reported that the thickness of mud layers above the sea bed could be measured by changing alternately from a high frequency (400 kHz) to a low frequency (28 kHz).

Nishimura (1968) has recently introduced a technological theory to obtain the optimum frequency for echo sounding. Several factors are involved in the propagation of sound, such as: attenuation of sound caused by absorption in sea water, cruising attenuation caused by a bubble layer generated below the bottom of the boat, reflection loss of fish, and vessel cruising noise. These factors either decrease or increase when the sonic frequency is changed. There should exist, consequently, some frequency at which the propagational loss becomes minimum. In other words, there is an optimum frequency at which the required total acoustic power output from

the transducer becomes minimum to detect fish at a given depth.

In vertical detection of fish schools, the relation between the depth of fish X(km) and the frequency $f_{t(min)}$(kHz) at which total acoustic power output becomes minimum to detect fish at depth of X is given by the following equation:

$$X = 10.5\, f_{t(min)}^{-\frac{1}{3}} \quad (7.8 + \tfrac{2}{3} B\, f_{t(min)}^{-\frac{2}{3}}) \qquad (1)$$

where B is a factor independent of the frequency and given by

$$q = B f^{-\frac{2}{3}} \qquad (2)$$

where q is the value of cruising attenuation caused by air bubble generated below the bottom of the boat. Eq. 1 indicates that the frequency $f_{t(min)}$ is decided only by the value of B when the depth of fish is given. Consequently the selection of the frequency depends heavily on the cruising attenuation which is affected by the sea state, speed and form of boat, and method of installation of transducers on the bottom of boat.

The maximum acoustic power output of transducers is limited by the cavitation generated in front of the transducer and by fatigue of the transducer. If the acoustic power output density corresponding to the calculated frequency $f_{t(min)}$ exceeds this limit, then this calculated frequency does not indicate the optimum frequency. In such a case, the frequency at which the output power density is equal to the limit becomes the optimum frequency to detect fish at depth X. On the other hand, the size of transducers must be considered in determination of optimum frequency.

Details are not mentioned here, but in a few words, low frequency must be selected when the depth of fish to be detected is deep or the value of cruising attenuation is small. On the other hand, high frequency must be selected when the depth of fish is shallow or the value of cruising attenuation is great. Details of the author's theory will be published in the near future in English.

Fish counting system

In Japan, several kinds of automatic acoustic fish counting systems are being developed using electronic computers that will count individual fish such as tuna, and grouped fish such as sardines or mackerel. In the former case, the number of fish is indicated as density of the fish school (the ratio between fish and water mass). In the latter case, the abundance of fish is indicated by an index showing thickness and length of the fish school.

There is also an optical fish counter which was developed by Shibata and Aoyama (1969). In this system the density and the area of the echo trace on the recording paper is calculated by an optical densitometer. The abundance of fish appearing on the recording paper can be indicated by the index proportional to the abundance of the fish school. Ishii and Tanaka (1969) have developed a "Pattern analysis system" in which the electronic computer discriminates and calculates automatically only signals of certain species of fish.

The above-mentioned systems will be used in future not only to investigate fish abundance but to indicate good fishing grounds.

Investigation of D.S.L. and S.L.

Using high-powered echo sounders, it is possible to obtain echo traces showing the structure of ocean, that is, migratory scattering layer (D.S.L.), non-migratory scattering layer (S.L.), and internal wave and surface reverberations. H. Yamanaka and others (1966) have carried out investigations observing the D.S.L. aboard the M.S. Shunyo-Maru along a course from Tokyo to New Caledonia and back to Tokyo. They have obtained a lot of data about moving speed, distribution, acoustic intensity of the D.S.L. and the relationship to fish schools.

Tawara and others (1967 and 1968) have also investigated the vertical distribution of the D.S.L. by regions aboard the M.S. *Koyo-Maru* on almost the same course mentioned above. It has been observed that tuna changes its swimming depth depending on the depth of the D.S.L. and that distribution of the D.S.L. differs by regional groups. It appears that their results meet with that obtained by Yamanaka. The relation between the appearance of the D.S.L. and the formation of fishing grounds is not yet clarified so the studies must be extended for longer periods and in a wide area to get an index of potential productivity of the ocean.

Nishimura and Shibata (1966) have published results of their observation and analysis of the relation between the appearance of S.L. and oceanographic conditions, and they concluded that the main factors of S.L. formation is due to the thermocline or discontinuity of vertical distribution of oxygen. Recently, the author has obtained data showing a clear correlation between the appearance of S.L. and thermocline near the boundary of Kuroshiwo where a distinct thermocline was observed.

PERFORMANCE OF JAPANESE ECHO SOUNDERS

The various types of echo sounders used on fishing boats have a variety of display systems, recording paper, frequencies, range, voltage of power supply, acoustic output power, etc.

There are more than three types of echo indicators. These are: the PPI scope as is applied in radar, paper recording, cathode ray oscillograph and audio systems. Most fishing boats install an echo sounder with the paper recording system alone or combined with a cathode ray oscillograph, but recently, the audio system is being adopted for use with sonar in purse seining to get rapid information on the movement of fish schools.

In the paper indication system, both dry and wet paper are used, while the stylus is driven by a rotating arm or by a belt. To get a linear indication of the sea bed and fish school trace, the belt system is mainly used. Recently, a multiple stylus system has been developed. In this system, more than 300 styluses are arranged in a single row.

Transducers

The material used in the construction of magnetostrictive type transducers is either nickel-iron or ferite, and Barium titanate is used in the electrostrictive types. The former is used generally for frequencies below 50 kHz

and the latter for high frequency above 50 kHz. Recently a transducer has been developed which can transmit two or three different frequencies. This would enable the number of transducers required for multi frequency echo sounders to be decreased.

Sonar

The PPI (Plan Positioning Indication) system sonar and paper recording system sonar were developed in 1956–1957, but due to excessive cost at that time, they were not generally applied in fishing operations. Recently, fishing methods have changed, and mechanization and automation of fishing operations have required new devices for fish detection, so the sonar became important, especially in purse seine fishing.

Since the maximum detecting distance of fish schools with sonar is limited by refraction of the sound beam, horizontal attenuation of sound, and reflection of sound on the fish body, sonar could be used only to detect dense fish schools at low speed within a range of 700 to 1,000 m. Results of the author's experiments, show that detection of tuna swimming at high speed and in irregular directions was difficult, and the maximum distance of detection of grouped fish is about 1,000 m. Detection of individual fish such as skipjack is limited to 600 or 700 m.

Telemetering systems in the trawl net

A few years ago, the wired sonic telemetering system was used to determine the depth of fish and the net in midwater trawl fishing. In this system, ultrasonic transducers were installed on the top of the trawl net or on the towing wire, with a cable connection to the trawler. Since operation of electric cables of more than 1,000 m length is difficult an acoustic telemetering system has been developed and is being used on Japanese trawlers.

There are two types of acoustic telemetering systems using either a dynamic or acoustic sensor. In the former, depth of net is measured by water pressure (bellows) and the variation of pressure controls the frequency of sound which is transmitted to the vessel. The information about depth is then converted to electronic information on board and is indicated on a recorder of the echo sounder. This system is also used to measure the sinking speed of purse seine nets.

The newest acoustic telemetering system was developed as recently as 1968. In this system, information about the net and fish is obtained by an echo sounding system and is sent up to the trawler by means of sonic carrier. The device, composed of an echo sounding system, transmitter and transducers is installed on top of the net or on the towing wire of the trawl net. Information about existence of fish, height of net opening and distance between net and sea bed is obtained first by the echo sounding system. This information is then converted into an acoustic signal which is transmitted toward the vessel. The acoustic carrier is received by a receiving transducer which has a streamlined cover and is towed from the trawler.

Fishermen can, therefore, get information of fish in the net and depth of the net on a shipboard recorder. Since the echo sounder is combined with this system, the net can be adjusted to the exact depth of the fish school detected by the echo sounder. In this device the maximum operational depth is about 500 m while the maximum distance of telecommunication between trawler and net is more than 1,000 m.

Kato and Nonaka (1968) reported on the relation between the trace of a fish school obtained by the "Net Recorder" and the catch while trawl fishing in the Northern Pacific Ocean. They report that the integrated area of fish school as it appeared on the echo chart was proportional to the catch of fish.

CONCLUSION

Currently much progress in the fishing industry cannot be expected because it is difficult to employ crews for fishing boats. This is caused by economic competition with land industry, a decrease of fishery resources around Japan and other economic and political reasons. This results in a slowdown of progress in acoustic engineering for the fishing industry. In the immediate future, improvements in acoustic technology will mainly be of benefit in the investigation of fisheries resources.

On the other hand, as ocean exploitation is now discussed actively world wide, many new acoustic devices will be developed and the fishing industry will share the benefits.

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Multi-stylus Echo Recording

I. Tanaka

Enregistrement d'echo par multistyle

Un nouveau type d'écho-sondeur avec enregistrement à style multiple (MSRS) a été mis au point. Il emploie un train en forme de peigne de styles stationnaires espacés à raison d'environ 2,5 unités par millimètre, balayés électroniquement à des vitesses variées. Son principal advantage est qu'il peut produire sans implication mécanique une vue dilatée de l'écho-sondage sur des accroissements de distance relativement courts. L'enregistrement simultané de deux ou plusieurs différents signaux est possible par une légère modification des circuits soit en groupant les styles en plusieurs séries, soit en changeant la vitesse d'enregistrement. Le système présente aussi des avantages pour la représentation d'une télémesure sous-marine sans câble du fait d'un circuit à enclenchement synchrone.

Registro acustico con aguja multiple

Se ha creado un neuvo tipo de ecosonda con un sistema de registro con aguja múltiple. Consiste en una serie de agujas fijas en forma de peine epaciadas aproximadamente 2,5 unidades por milímetros, que son explorados electrónicamente a distintas velocidades. Su principal ventaja es que puede ofrecer una presentacion visual ampliado del eco con incrementos relativamente pequeños de la distancia sin necesidad de dispositivos mecanicos. Es posible el registro simultáneo de dos o más señales diferentes modificando ligeramente el circuito, ya sea agrupando las agujas en varios bloques o cambiando la velocidad de registro. El sistema tiene también ventajas en la telemetría submarina inalámbrica debido un circuito de cierre sincrónico.

CONVENTIONAL echo sounder recorders employ a stylus made of hard material, such as tungsten connected to a motor-driven disc or belt and recording paper, the colour of which is changed by electro-discharge induced by the echo signals which are amplified and applied to the stylus rotating in contact with the recording paper. The time it takes the sound to travel between the target and transducer is measured by the speed of rotation of the stylus which must be increased with decreasing measuring range. Because of the inertia of the stylus and mount the minimum measuring range of this system is about 10 m in water.

The inertia problem also limits the stylus rotation to a constant speed making it impossible to simultaneously record two or more different measuring ranges on the same rotation because this would require varying the speed.

The newly developed multi-stylus recording system (MSRS) employs a comb-like train of stationary styluses having a density of approximately 2.5 styluses per millimeter.

This train of styluses is electronically scanned also at varied speeds and in the desired directions. The system permits more enlarged recording of objects than with a mechanical stylus and can even record fish schools near the surface.

The multi-stylus echo sounder (comb-stylo) has been in wide use since the spring of 1968 and has made a great contribution to the Japanese fishing industry.

PRINCIPLE OF OPERATION

The recording mechanism consists of a large number of recording styluses electrically insulated and separated from one another by moulding. The recording paper is fed in the same direction as it is held in contact with the styluses. Both types of recording paper, wet and dry, can be used. Feeding and take-up of the recording paper are performed by independent constant speed motors so that signals applied between any of the styluses and the ground plate are recorded by the stylus over the portion of the recording paper at which the stylus is located and over the period that the signals are applied. The clarity of recorded images, of course, depends upon the density of the lines and is improved by making the styluses as thin as possible as well as minimizing the separation between them. The line density of instruments now on the market is approximately 2.5 lines per millimeter.

A schematic diagram of the electrical circuitry is shown in fig 1. The reference signal f0 generated by a reference signal oscillator is counted by a counter which employs the base of N and generally consists of a certain number of cascaded binary counter circuits. The counter is equipped with counting output terminals, denoted 1, 2, 3, . . . n, which are connected to the corresponding AND gates G1, G2, G3, . . . Gn.

After counting n of the reference signals, the counter is automatically reset to zero by means of a reset signal

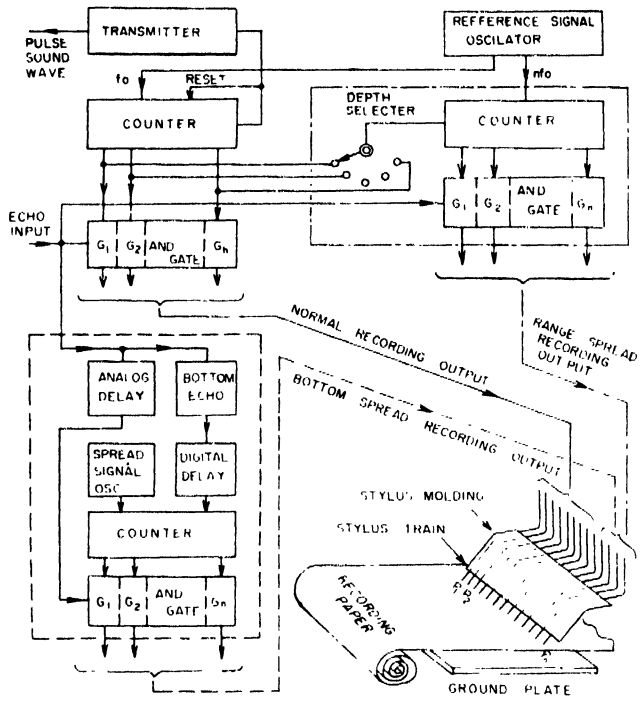

Fig 1. Schematic diagram of MSRS

and then starts another count beginning with 1. Therefore, the period the control signal is supplied from the counter to the AND gates is $\frac{n}{f0}$ (seconds).

Input signals are fed to the other terminals of the two parallel AND gates when they coincide with the control signal to open the gate and permit them to pass through. The output terminals of the individual gates are connected to their respective recording styluses (P1, P2, P3, . . . Pn) to record the input signal on the recording paper. Thus, the positions of the styluses and the recording time are electrically determined instead of mechanically and the recording speed as well as recording accuracy are considerably improved as compared to the conventional mechanical scanning.

In this system the speed of recording and recording accuracy are directly dependent on the accuracy of the reference signal frequency f0 and its value. The highest possible value is determined by the counting speed of the counter and the minimum recording period required by the paper for recording. These conditions have been shown by research to be capable of recording 1 μs signals with a counter having an operating speed of 1 MHz. An accuracy of 10^{-4} for f0 can be easily obtained by the use of a crystal controlled oscillator. This performance is theoretically equivalent to 22.5 cm full scale which can be obtained with an echo sounder employing 300 recording styluses at a frequency f0 of 1 MHz.

Recording of two or more different signals with the styluses grouped into several blocks on the same recording paper is possible by slightly modifying the scheme shown in fig 1.

APPLICATIONS

The fact that only the paper take-up is mechanical makes the electronic scanning recorder suitable even for such unfavourable operating conditions when strong vibrations prohibit the use of conventional ink-trace recorders. Other major advantages of this system are simultaneous recording of different signals and extremely high-speed recording.

The first step in oceanic exploration now being taken up as a national project by quite a few nations will be the investigation of the sea floor. High-speed and high accuracy recording are necessary to improve this exploration. This is yet another field in which the electronic recording system will prove useful.

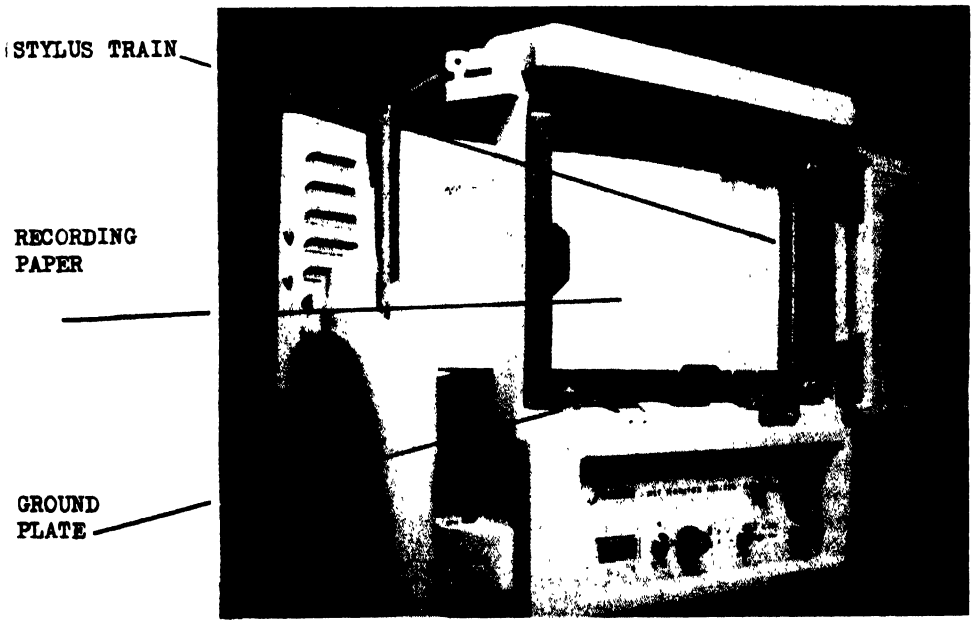

Fig 2. Recorder of multi-stylus echo sounder

Several more applications of the multi-stylus system can be described.

Underwater telemeter recorder

The synchron characteristics of the multi-stylus recording system (MSRS) can be utilized for wireless underwater telemetry. Ultrasonic pulses are emitted from transducers of the Net Monitor (fig 3) both downward (towards the sea floor) and upwards (towards the surface). The echoes are received, amplified, modulated and transmitted in pulse form towards the receiver which is towed by the vessel. The received ultrasonic pulses are then amplified and evaluated to extract the synchron signal and the echo in order to synchronize the receiver and record the echoes.

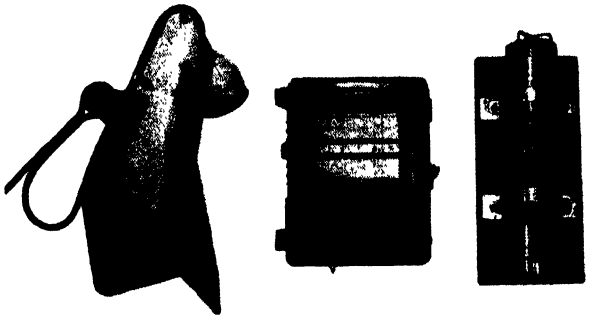

Fig 3. Fishing net monitoring equipment. NM-850 net monitor. (left) submerged receiver; (middle) multi stylus recorder; (right) detecting transmitter

Since the electronic recorder is extremely responsive with little inertia and provides a stable record even with weak ultrasonic pulses, telemetering over long distances is possible. The system can also be utilized to remotely monitor underwater objects. The use of submersed or towed transducers will permit more precise investigation of the sea floor and underwater objects.

Furthermore, transducers installed at the required locations in bays or near fishing nets will also aid in the remote monitoring and recording of vessel and fish movements.

Simultaneous multi-trace detector recorder

This detector utilizes the feature of the multi-stylus recording system that permits it to divide the recording range into the required parts. For example, sound pulses are emitted simultaneously in four directions and the echoes in the beam range of each transducer are amplified, detected, and fed into a four trace multi-stylus recorder to conduct fish finding over a wide sector of the sea without actually scanning it (fig 4). This improves the scanning time and range considerably as compared to conventional mechanically scanning sonars.

Ultrasonic pulses can also be directed from the surface of the sea obliquely towards the sea floor which permits the detection of hidden obstacles and schools of fish ahead of the ship.

The multi-trace multi-stylus circuit also permits changing of the recording speed as required to enable recording of several different types of information on

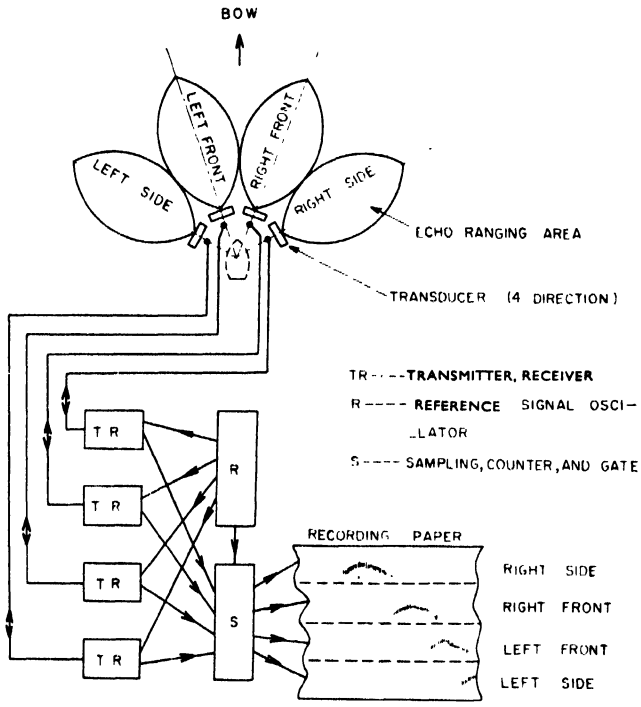

Fig 4. Simultaneous multi-direction sonar

different channels of the record. In particular, when employed for both detection of the sea floor and fish schools from high speed ships the capability to discriminate direction and the extremely wide range of detection will provide far better performance with less blind area than conventional sonars.

Bottom spread echo sounder

The echo sounder which utilizes the MSRS high recording speed and simultaneous multi-tracing finds its widest use in bottom trawling because it can record schools of bottom fish located very near the sea floor. The upper three-fourths of the recording paper are used for normal echo sounding and the lower one-fourth for expanded recording of a range of 3, 6 or 12 m above the ground with bottom lock.

The echo sounder is equipped with the electronic circuit shown by the broken lines in fig 1.

The train of styluses (P_n–1, P_n) which record the lower one-fourth of the recording paper are scanned by a bottom echo counter in reference to the sea floor echoes which are generally the strongest, and are fed with the echoes from an area located at a predetermined height from the sea floor.

Range spread echo sounder

The range spread echo sounder also utilizes the MSRS high recording speed and simultaneous multi-tracing and uses the upper half of the recording paper for normal recordings and the lower half for expanded recording of the desired depth section.

The range spread echo sounder is particularly suitable for pelagic fish schools of e.g. tuna, mackerel, herring and for purse seining and midwater trawling. It employs the electronic circuit shown by the chain lines in fig 1.

The signal for the depth to be expanded is extracted from a counter by a selector and supplied to an independent spread counter together with the output of the reference oscillator to actuate the gate circuit which produces expanded recordings of echoes at the desired depth.

RECORDING SAMPLES

Fig 5 and 6 show samples of MSRS recordings produced by the Net Monitor (netsonde) equipment attached to the headrope of a bottom trawlnet. Fig 5 is a recording of approximately 11 min. It shows that it

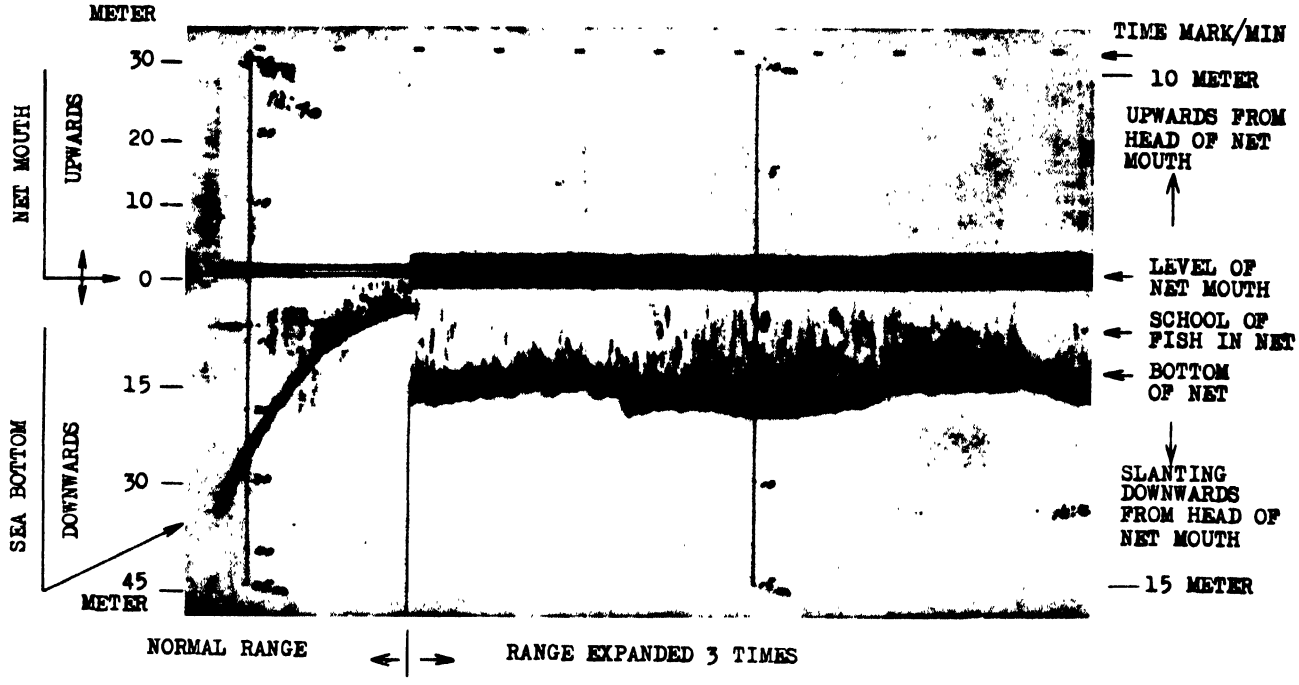

Fig 5. Net Monitor: *NM–850*
Frequency: *detecting 200 kHz, telemetering 50 kHz*
Warp length: *750 meters*
Fish: *cod*
Place: *Off West Kamchatka, Okhotsk Sea*
Depth: *275 meters*

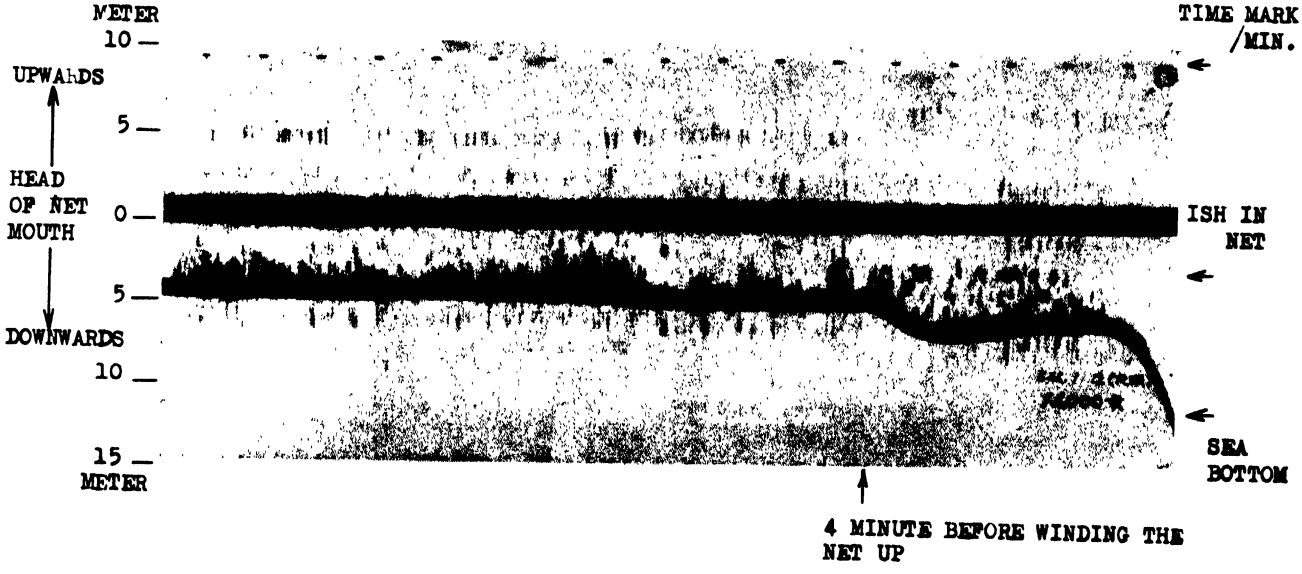

Fig 6. Net Monitor: *NM–850*
Frequency: *detecting 200 kHz, telemetering 50 kHz*
Warp length: *750 meters*
Fish: *cod*
Place: *Off West Kamchatka, Okhotsk Sea*
Depth: *270 meters*

took approximately three minutes for the headline to descend from 35 m above bottom to approximately 6 m distance (where the target is) from the sea floor.

The fish in the net opening is clearly recorded because the MSRS range was expanded three times when the headrope reached its proper distance of 6 m from the sea floor. No fish are recorded above the headline in this sample. This is probably because they all fled toward the sea floor when the gear approached and were thus caught. The catch was approximately 40 T.

Fig 6 is a Net Monitor record taken immediately before hauling the trawl in. It appears that about 4 min

Fig 7. Echo Sounder: *SRM-680, normal recording*
Frequency: *200 kHz*
Place: *Sagami Bay, Japan*
Fish: *Sardine*

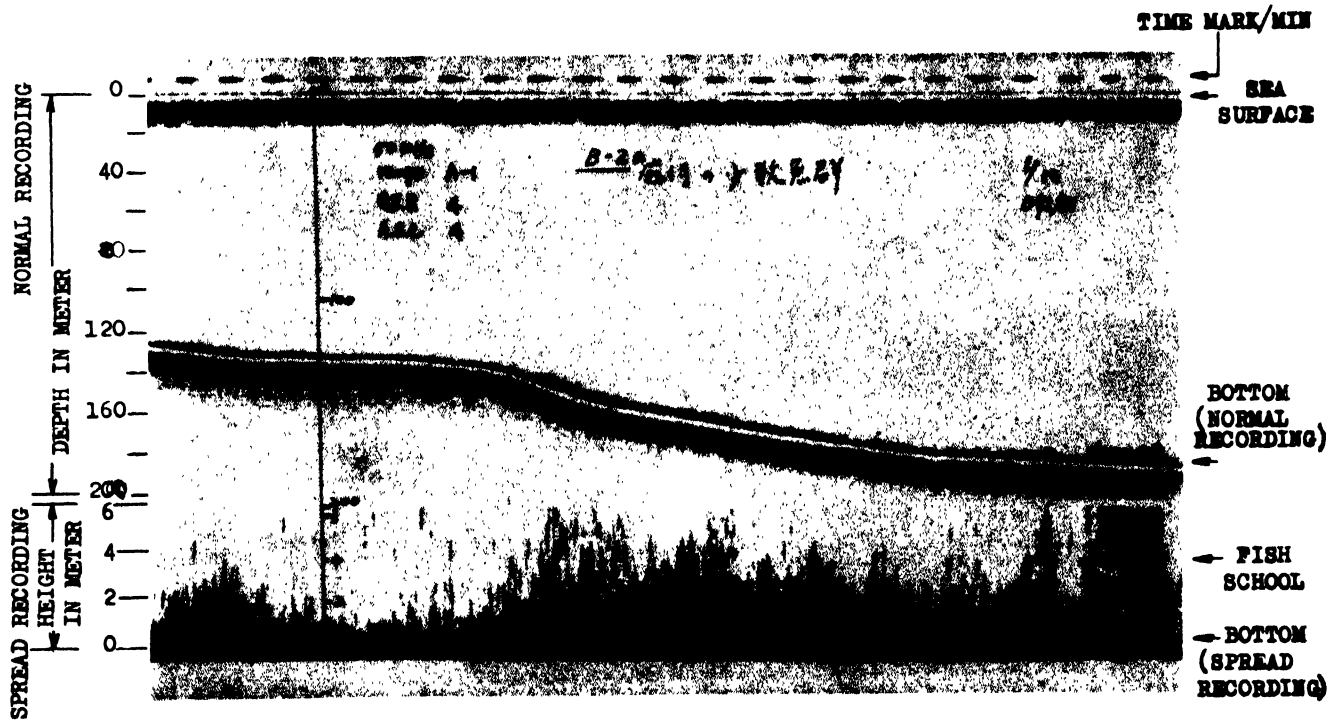

Fig 8. Echo sounder: *Bottom spread, SRM-871*
Frequency: *50 kHz*
Place: *Off Sakhalin, Okhotsk Sea*
Fish: *Cod*

Fig 9. Echo sounder: *Bottom spread, SRM–872*
Frequency: *50 kHz*
Place: *Off West Kamchatka, Okhotsk Sea*
Fish: *Cod*

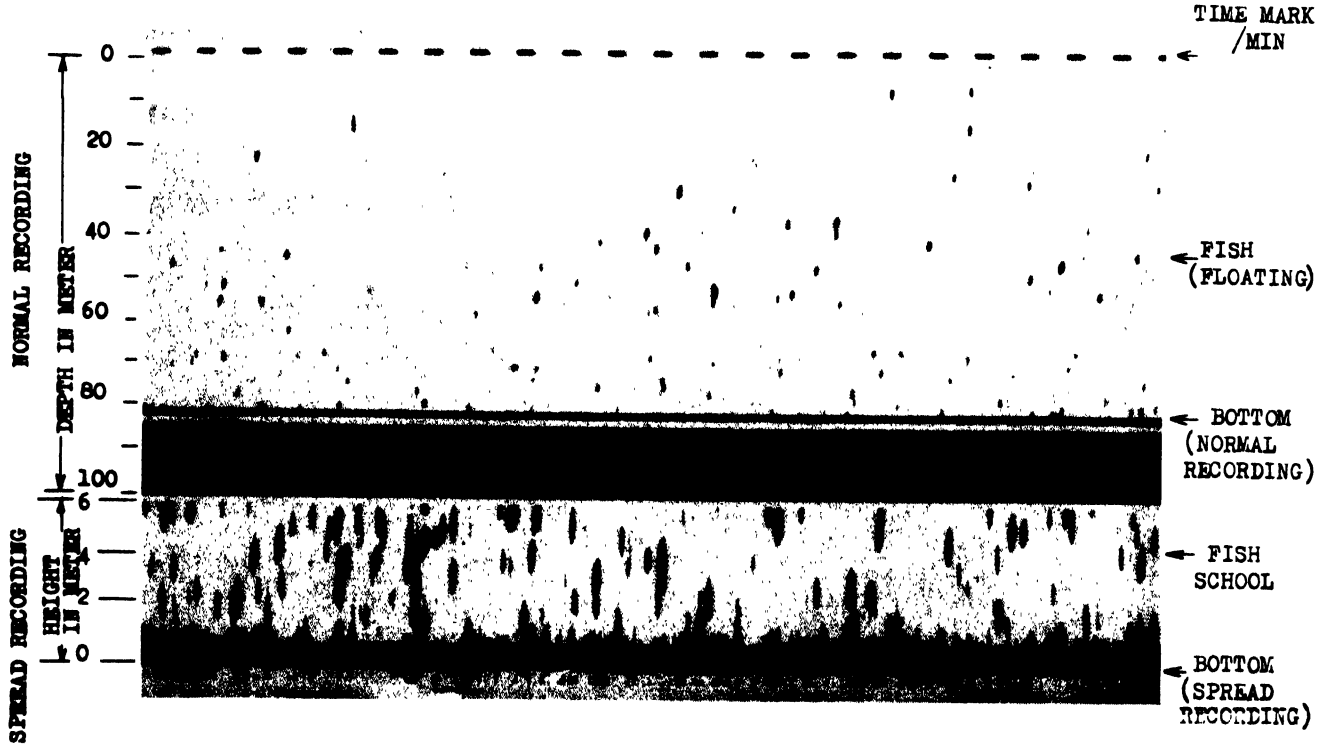

Fig 10. Echo Sounder: *Bottom spread, SRM–681*
Frequency: *200 kHz*
Place: *East China Sea*
Fish: *Croaker*

before hauling the headrope rose approximately 7 m from the sea floor. This is because the net was full of fish. The catch was about 50 T.

Fig 7 is a sample recording taken by a shallow water MSRS whose full range is 10 m. It clearly shows schools of small sardines approximately 6 m deep. These sardines are less than 5 cm long and referred to as Shirasu in Japan. They cannot be recorded clearly but would appear as cloud with conventional echo sounders.

Fig 8 is a sample recording of schools of cod near the sea floor approximately 120 to 160 m deep. In this sample normal range and bottom spread are simultaneously recorded by a bottom spread type MSRS. This facilitates observation of the density, distribution and position of the schools of fish near the sea floor because the sloping surface of the sea floor is corrected to be level and flat by means of the bottom lock. The rate of expansion near the sea floor is effectively ten times.

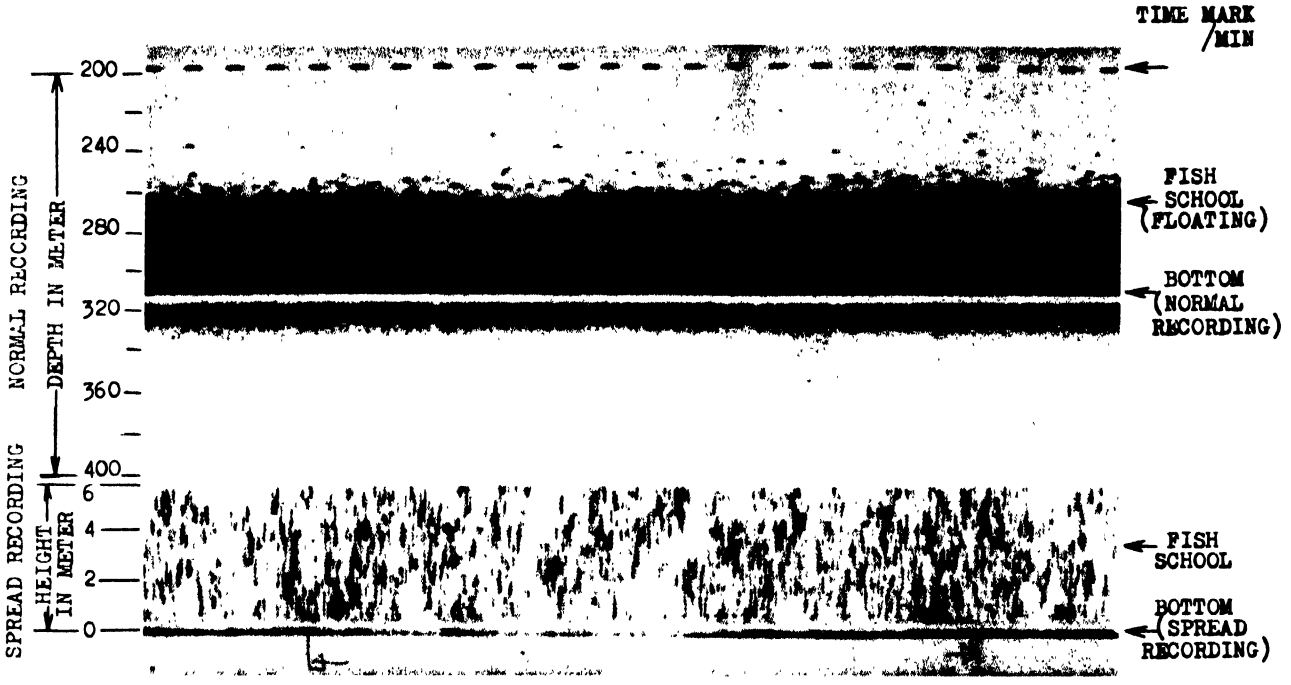

Fig 11. Echo Sounder: *SRM-872*
Frequency: *50 kHz*
Place: *Off West Kamchatka, Okhotsk Sea*
Fish: *Cod*

Fig 12. Echo Sounder: *Range spread, SRM-682*
Frequency: *200 kHz*
Place: *Tokyo Bay*
Fish: *Horse Mackerel*

Since these schools of fish extend to the sea floor, the fishing ground is suitable for bottom trawling.

Fig 9 is a recording of schools of cod near the sea floor approximately 290 m deep including a bottom spread recording at 6 m range. This sample shows that bottom trawling should be aimed at the schools towards the right from the centre because although the left-hand fish schools are larger they are mostly off the sea floor and could be caught better by midwater trawling.

Fig 10 is a recording of schools of croaker near the sea floor approximately 80 m deep including a bottom spread of 6 m range from the sea floor. The bottom spread was recorded at a higher sensitivity than the normal recording to facilitate observation of conditions near the sea floor.

Fig 11 is a recording of schools of cod near the sea floor approximately 300 m deep and shows that they are large but at a comparatively low density. They may be bottom trawled after having settled or midwater trawled.

Fig 12 is a recording of a school of small horse mackerel located approximately 20 fm, taken by a range spread type MSRS and includes a five times expanded recording of the 16 to 24 fm range of the normal recording. The sea floor is recorded like saw teeth due to the irregularities of the terrain and pitching and rolling of the ship. This is because the bottom lock is not utilized. Small schools of fish would have appeared in midwater if the spread range had been shifted towards the surface and the sensitivity increased.

Fig 13 is a cuttle fish being attracted and lifted by a dummy bait hook in approximately 80 m depth. A number of cuttle fish are also observed below it. The range spread included covers the 80 to 100 m range of the normal recording. The rate of expansion is five times. The range spread is useful for determining whether fishing should be continued or not because it clearly records the distribution of cuttle fish.

CONCLUSION

The multi-stylus echo sounder provides truly new aspects in fish finding because of its high recording speed, multi-tracing and highly stable synchronization which are impossible to realise with conventional echo sounders.

The MSRS will also find application in oceanic exploitation and investigation as a sector sonar or doppler shift recorder.

Acknowledgement

Our thanks are due to Dr Y Maniwa of the Fishing Boat Laboratory of the Fisheries Agency for his great assistance in developing practical MSRS sets.

Fig 13. Echo Sounder: Range spread, SRM-873
Frequency: 200 kHz
Place: Off Hachinohe, Japan
Fish: Cuttle fish

Hydroacoustic Fish Finding and Instrumented Gear Control in Purse Seining and Trawling

V. I. Kudryavtsev

Etat actuel de la detection hydroacoustique du poisson et de controle par instruments de l'engin dans la pêche à la seine coulissante et au chalut

On trouve en URSS quatre types d'écho-sondeurs et deux types de sonars avec de fréquences comprises entre 19,7 et 160 kHz et des portées maximales de 160 à 2800 m, selon les besoins particuliers des différentes catégories de navires. La pêche à la seine coulissante avec sonar est bien au point; elle comporte, dans le cas des poissons particulièrement vivaces, l'utilisation de bateaux annexes équipés de sonars et une télémesure de la profondeur pour observer la plongée de la seine. Pour la pêche continentale en hiver, on met au point actuellement un écho-sondeur pouvant détecter le poisson au travers de la glace, ainsi qu'un sondeur pour la détection du poisson de fond par plus de 1000 m. Des recherches sont faites sur la détection du poisson par écoute passive au moyen d'un équipement spécial à sensibilité directionnelle. On étudie actuellement des sonars avec projecteur monté sur un dispositif pouvant être remorqué à diverses profondeurs par navire ou hélicoptère. Pour la télémesure de la profondeur par sondeur de chalut (netzsonde), on préfère employer la liaison par câble, mais pour la mesure de la profondeur par la pression on emploie également la liaison acoustique. Des essais sont en cours sur les multinetzsondes à plusieurs projecteurs (un vers le haut, un vers le bas et quatre vere l'avant) et sur un système de télémesure sans câble pour la profondeur du chalut, la hauteur d'ouverture, la distance du fond, la température dans le filet et la quantité de poisson capturé.

Situación actual de la localización hidroacustica de peces y regulación mecanica de los artes cuando se pesca con redes de cerco y arrastre

En la U.R.S.S. se emplean cuantro clases de ecosondas y dos de sonar con frecuencias entre 19,7 y 160 kHz y alcances máximos de 160 a 2800 m, que se ajustan a las necesidades de barcos de todas clases. Está muy perfeccionada la pesca con redes de cerco dirigida con sonar, comprendido el empleo de botes pequeños en los que se instalan los aparatos cuando se trata de peces muy activos y de la batitelemetría para observar el hundimiento de la red. Se atrae a la caballa con luces cuando es objeto de pesca con redes de cerco. Para la pesca continental en invierno, se fabrica una ecosonda detectora que funciona a través de hielo y otra para localizar peces del fondo a más de 1000 m de profundidad. Se estudia la detección de peces mediante la escucha pasiva, empleando equipo especialmente sensible a la dirección de la que procede el sonido. Se piensa en la construcción de aparatos de sonar con dispositivos transductores que pueden remolcar a diversas profundidades barcos o helicópteros. Para el ecosondeo se prefieren batitelémetros (netsonde) instalados en la red, y con comunicación por cable, pero también se emplea la acústica en las ecosondas que funcionan por afecto de la presión. Son objeto de ensayos dispositivos batitelemétricos con varios transductores (arriba y abajo y cuatro direcciones hacia adelante) y un sistema de telemetría inalámbrica para determinar la profundidad a que está el arte, la abertura vertical, la distancia a que se encuentra del fondo, la temperatura en la red y la cantidad de peces dentro de ella.

SUCCESSFUL fishing in the open seas materially depends on hydroacoustic instruments which make it possible to reduce time spent in finding fish.

Modern fishing ships are now equipped with a complex of various hydroacoustic machines, including sonars, echo sounders, and telemetering apparatus for monitoring trawl parameters. Purse seiners are also fitted with instruments which determine the time and depth of sinking of the purse seine leadline.

When used in conjunction with other data (hydrological and hydrobiological), the information obtained during hydroacoustic reconnaissance makes it possible to prepare forecasts for the fishing fleet and effect rearrangements if desirable.

The hydroacoustic intruments installed on research and experimental ships carrying out fish investigations are used for the study of fish behaviour, their location, migration (vertical, horizontal, daily and seasonal), response to fishing gear, light and other external stimulants with a view to improving existing fishing gear and methods and preparation of long term fishing forecasts.

SPECIFICATIONS OF FISH FINDING EQUIPMENT

At present the fishing fleet of the USSR is predominantly equipped with Soviet-made hydroacoustic fish finding devices. A variety of fish finding echo sounders and sonars (Table 1) are available for all types of fishing vessels from the smallest to the largest freezing trawlers (fig 1).

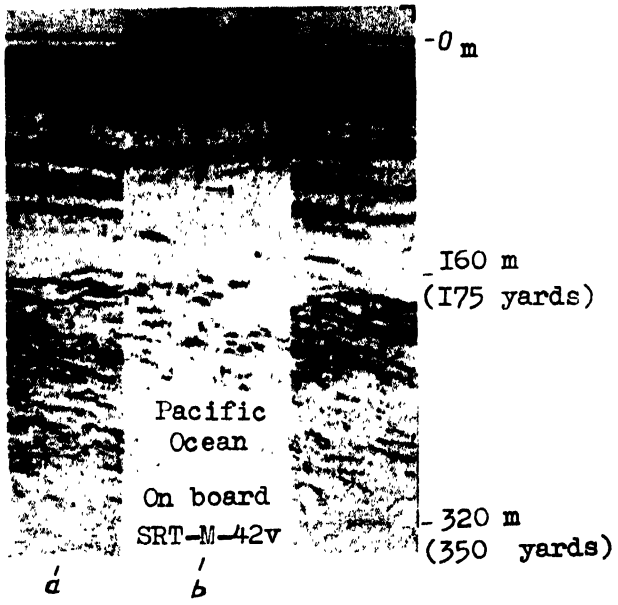

Fig 1. Recording of scattered fish by "Omar" echo-sounder.
a — low frequency25.5 kHz trace
b — high frequency 160 kHz trace

HYDROACOUSTIC INSTRUMENTS IN PURSE SEINING

During purse seining, sonars are used for search and detection of schools, determination of their vertical and

TABLE 1. HYDROACOUSTIC INSTRUMENTS PRODUCED IN U.S.S.R.

Type	*Frequency kHz*	*Maximum range (m)*	*Application*	*Remarks*
Yaz	81	160	inshore fishing auxiliary boats	weight 5 kg
Sudak	25.5	900	navigation medium size vessels	
Omar	25.5 160	920	medium size vessel	(see fig 1)
Kalmar	19.7	2,800	large vessels	also with 800 mm extended transducer installation
Sonar Omul	25.5	2,800	medium size vessels	incl. vertical transducer
Paltus-M	19.7	2,800* 4,000†	large vessels	ditto

Notes: (1) All instruments have the "white line" fish discrimination feature.
(2) Presentation may be by recorder tape, C.R.T. or neon tube flasher.
(3) Some instruments have a signal amplitude indicator for measurement of target strength.

*scanning. †sounding.

horizontal size and movements and for guidance of ship during seining.

Experience has shown that the tactics of purse seining with sonars depend on the type of fish, their behaviour (which may vary by seasons) and on the hydrological conditions which also may vary by seasons. On some occasions herring are calm and the ship, having detected the school by sonar, may pass over them and determine

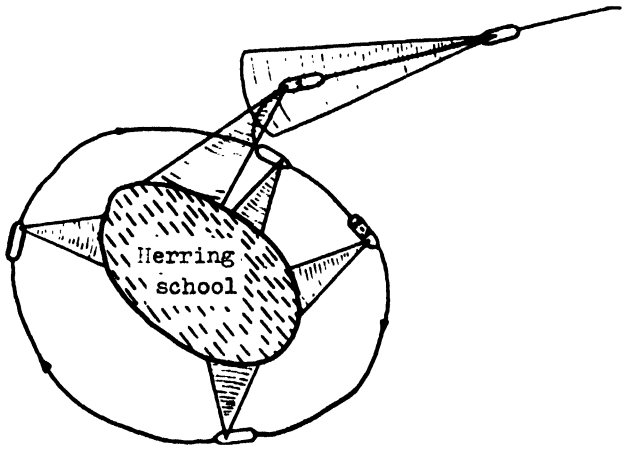

Fig 2. Sonar diagram of a fish school during shooting of a purse seine

exact dimensions and depth, but in general, herring respond rapidly to noise of vessels and sink to depths where they cannot be seined. Therefore, it is not advisable to cross the school during purse seining.

Accuracy of quantitative evaluation of the school depends on the skill of the operator. The most accurate evaluation is obtained with the use of the cathode ray tube (CRT) indicator with type "A" sweep. The depth of the school is determined by the angle of tilt of transducer and distance to school. Having determined boundaries of the school the distance between ship and school to be maintained during shooting the seine (figs 2 and 3) is worked out.

At point of shooting the ship should turn in to the wind, leaving the school at an angle of 15 to 25° starboard. Shooting generally starts at a distance of 150 to 70 m

Fig 3. Echogram of herring school, during shooting of a purse seine, made by the "Paltus-M" sonar
a – approach to the school to check its behaviour
b – school during shooting of the seine

(170 to 77 yd) from the school. In the course of shooting, the relative bearing to the left edge of the school will gradually increase. When it reaches 60 to 70° the ship should be steered into a starboard circle proceeding to the initial point of shooting. During pursing periodically check depth of lower edge and centre of school. During shooting the amplification factor and pulse length are reduced to facilitate discrimination of the fish echo signal from the noise of the wake.

Sometimes schools are located at great depth. Then the ship, after checking with sonar, should stay at distance from the school with bow to the wind and periodically check by sonar. Seining is started only when the school rises sufficiently.

During purse seining in shallow depths, i.e. 40 to 110 m (44 to 120 yd), fish finding equipment is used in a somewhat peculiar way. In daytime herring schools sometimes keep close to the bottom. In this case they are detected by echo sounder and the ship stays in position until the fish schools rise to the level for seining.

In the Far East, herring schools are characterized by low activity and are sometimes purse seined by small ships with the help of search ships.

Great skill and experience are required from the sonar operator when purse seining for scombrids which are characterized by rapid mobility and acute response to ship noise. Sombrids may develop speeds over 10 kn, suddenly change their direction of movement and quickly sound to a depth of more than 100 m (109 yd). Scombrids have a lower signal reflecting ability than herring, and cannot be detected by sonar at long ranges.

Scombrid purse seining is accomplished only by use of sonar. If attempts are made to assess the school by echo sounding it rushes away or scatters.

During certain periods of the year scombrids display a positive reaction to light which makes it possible to seine them with light attraction. In this case the seiner detects the school with sonar. At a distance of about 200 m (220 yd) the engine is shut down and the ship reaches the school by inertia. Then the lights are turned on and the fish gather under the ship's hull. This is checked by echo sounding. After fish are gathered, a boat equipped with lights and a small echo sounder is lowered and the seiner turns off its lights and moves off to a distance required for shooting the seine.

The school is observed during seining with the echo sounder in the small boat and with the ship-mounted sonar. During purse seining scombrids try to escape from the seine through the gap before pursing is finished. Experiments are being tried by sound irritants to prevent this.

The sonar operator who sometimes has to process a great amount of information within four or five minutes (duration of seining) is considerably assisted by circular scan indicators (CRT with plan position indication) which is employed at short distances of up to 500 m (550 yd). Circular scan indicators are available for the sonar types "Paltus-M" and "Omul" (fig 4), and have a CRT of 230 mm (9 in) in diameter. The circular scan rotates synchronized with the sonar transducer and the linear scan type "A" is similar to the scan employed for CRT display of fish finding echo sounders. The sonar may be triggered by the CRT which ensures a greater repetition rate at distances of about 300 m (330 yd) and thus improves the image of the school.

The experience gained by seiners, especially by those using large purse seines indicates the need of information on the time and depth of sinking of the purse seine lead-line. This information is needed to determine when to commence pursing as the rate of sinking may vary within wide limits and to provide it a hydroacoustic depth telemeter has been designed which is presently under test.

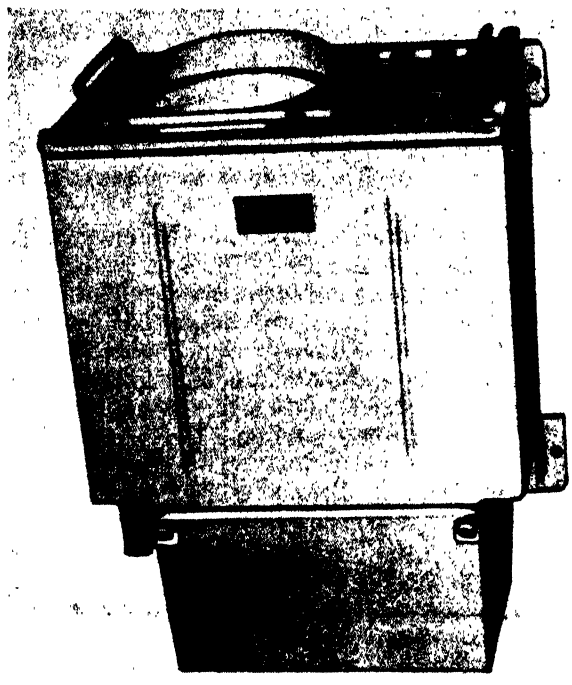

Fig 4. Electronic indicator with horizontal scanning (P.P.I. scope) for fish finding sonars (717 × 535 × 422 mm) (28 × 21 × 16 in)

To reduce the overall dimensions of the acoustic system use should be made of a second, high frequency channel of the sonar—"guidance channel". Purse seining with the use of the high frequency channel with a continuous or step-by-step scanning of a certain sector is quite practicable as in this event there is no need for a school detection range in excess of 500 to 600 m (550 to 660 yd) or a very great scanning sector. The use of high frequency is expedient also to obtain better resolution in distance and angle and avoid frightening of fish by ultrasonic radiation since it has been established that most fish respond only to sounds of relatively low frequencies.

FISH FINDING THROUGH ICE

Great attention is paid to the development of fisheries in the inland waters of the USSR (rivers, lakes and water reservoirs) for which echo sounders are employed so far only for fish finding in open water.

In winter, however, most lakes, reservoirs and rivers are covered with ice so that fishing becomes difficult. Then fishing areas have to be selected by past experience. Removing ice and setting fishing gear require considerable labour and time and results may often be poor. To increase efficiency of under-ice fishing a small-size echo sounder has been designed. The echo sounder has a maximum range of 270 m (300 yd), operates at a frequency of 30 kHz and is able to detect separate fish, 25 to 30 cm (10 to 12 in) long, through an ice cover of 80 to 85 cm (32 to 34 in) thick down to a depth of 80 m (88 yd).

During tests it was established that acoustic signals passing through ice are materially attenuated and when

ice thickness reaches 120 cm (3.9 ft) the range is considerably reduced. The range depends also on the ice structure as loose ice frequently found in the surface layer causes additional attenuation. This effect sometimes results in an increase of the "dead zone" due to a sort of "reverberation", i.e. multiple reflections from the lower and upper ice boundaries as well as from cracks in the ice.

At present, the most reliable method of under ice fish finding is "pin-point" searching. The echo sounder and power unit are mounted on a vehicle and the transducer is connected to the recorder by a cable of 25 m (27.5 yd) in length. The snow is removed from the ice, water is poured onto the ice and the transducer is placed on the moistened surface. This eliminates the air-water interface and ensures proper transfer of sonic energy through the ice.

DEEP SEA FISH FINDING

Some species form commercial concentrations at depths of 900 to 1200 m (990 to 1300 yd).

Effective detection of schools at such depths involves technical difficulties. First, the basic types of fish are bottom-dwelling; secondly, at these depths the valuable kinds of fish (halibut, coal fish, etc) form rather thin concentrations disguised by bottom irregularities.

An experimental model of an echo sounder designed for detection of single fish with reflection properties equivalent to that of a sphere of 10 cm (4 in) radius at depths of 1000 to 1200 m (1090 to 1300 yd) is being tested on artificial targets and bottom dwelling fish. A certain weight and the artificial targets (spheres) were attached at the lower end of a cable, 1200 m (1300 yd) long, and the upper end had several floats to ensure positive buoyancy of the whole assembly floating in the water. The ship approached these buoys at different relative bearings and at different speeds and recorded the targets on the experimental echo sounder (fig 5). Further tests involving actual detection of bottom-dwelling fish proved that the data obtained with artificial targets were similar to those obtained during actual detection of fish (fig 6).

Fig 5.

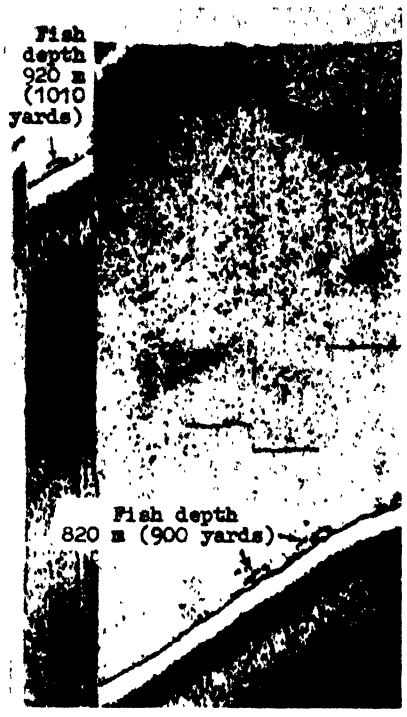

Fig 6.

Fig 5. Echogram of artificial targets made with the deep sea fish finding echo sounder at a depth of 1000 m (1090 yards); ship speed – 9 knots
1, 2, 3 – spheres, 200 to 400 mm (8–16 in) dia.; 4 – weight
Fig 6. Echogram of demersal fish recorded by a deep sea echo sounder at the depths of 920 m (1010 yards) and 800–840 m (875 920 yards) ship speed – 6–7 knots

FISH FINDING BY PASSIVE LOCATION

Investigations are being made to determine the possible use of a fish noise direction finding method for detection of objects which cannot be found by existing fish finding intruments. These objects include tunny fish, sharks (which do not form schools and may travel at high speed), and crustacea which commonly dwell at the bottom. Some of the crustacea may rise slightly above the sea bottom (e.g. shrimps) but do not as a rule form thick concentrations.

Research is also attempting to determine the species of fish schools. Scientific investigation of fish sounds may contribute to attracting or frightening fish and could be used to produce artificial concentrations or influence fish behaviour in other ways.

A fish noise direction finder has been developed which enables the simultaneous monitoring of underwater noise and sounds within 360° and takes bearings of the source of sound with an accuracy of 10°. It has a scanning frequency range of 100 to 30,000 Hz and the following series of narrow frequency ranges for analysis of the received sounds: 100 to 150 Hz, 350 to 1000 Hz, 2000 to 6000 Hz, 2000 to 16000 Hz, 16000 to 30000 Hz. The transducer assembly of the instrument is projected beyond the ship's hull with a special lowering equipment.

SONARS WITH TRANSDUCERS IN VARIABLE DEPTHS

Existing types of hydroacoustic fish finding equipment cannot provide for a further substantial increase in detection range due to hydrological limitations. During tests of long range detection of fish schools under various hydrological conditions it was found that the most advantageous instruments are those whose transducers may be adjusted to different depths by being lowered and towed. Sonars with towed transducers have many advantages such as normal operation under various hydrological conditions, increase of the radiated acoustic power by adjusting to a greater depth, decrease of ship noise level, decrease of storm sea noise, and better stabilization and directivity in calm layers of deeper water.

Sonars with towed transducers also have some specific disadvantages associated basically with the need for a special tow cable, winch gear and other space consuming

installations. Nevertheless, it is considered desirable to have such towed sonar equipment on research vessels. Such sonars may also be operated from helicopters based either on shore or on large ships. The advantage over the ship-mounted sonars is mainly the higher speed of search which gives it great potential for use on search ships.

TELEMETERING EQUIPMENT FOR CONTROLLING GEAR

Considerable progress has been achieved in developing and introducing telemetering instruments to aid control of trawl gear. These are useful in midwater and pair trawling.

Sonars are used for guiding the trawl to detect fish concentrations horizontally. The telemetering equipment is required to orient the trawl in the vertical plane during approach, for determination of the optimal time of trawling by indication of the filling of the trawl with fish, and for accurate determination of the trawl distance from the bottom. This equipment is at present being used either independently or in combination with indicators of the long range navigation system and is also used for aimed fishing by the "scooping" method of trawling employed in regions with difficult ground (fig 7). In this

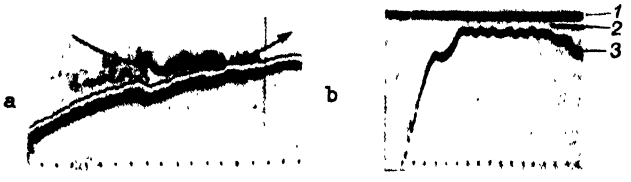

Fig 7. Fishing with a "scooping" method in areas with hard grounds by means of telemetric control apparatus
a = echogram of fish finding echo-sounder
b = telemeter echogram
1 = headline; 2 = fish in the trawl mouth; 3 = ground

event the trawler searches for fish concentrations near the uneven bottom, finds a comparatively even bottom area with fish schools, approaches this area by reference to the indications of the radio-navigation system and telemetering control equipment, and performs trawling (which is generally highly successful) within a short period of time.

In some areas fish are near the bottom only at certain times of the day whereas at other times (commonly at night) they rise. Use of telemetering intruments now makes it possible to perform trawling all round the clock which considerably adds to efficiency.

Communication

In the course of development, three types of communication channel have been considered: wire rope, cable (cable warp) and wireless hydroacoustic link.

The wire rope channel is based on transmission along the conventional trawl warps. The warps and sea water form a sort of short-circuited two-conductor line through which the electrical signals are transmitted. Experiments have shown that during transmission the electromagnetic oscillations are greatly attenuated even at comparatively low frequencies. Therefore ultra low frequency oscillations would be needed to obtain the required operating range.

Research on electrical cable communication lines has shown that they are a rather simple means for transmission of large amounts of information from trawl to ship. They feature high soundproof characteristics, but are not convenient in service since they require a separate cable and a separate winch. The cable operates under adverse conditions, is subject to rapid wear and has a comparatively short service life. Besides, the energy consumption is rather high.

Another version of cable communication is the warp with conductors which eliminate the need for a separate cable and a separate winch, but maintaining all the advantages of the cable communication line.

Special research proceeds on developing a reliable electrical cable warp to be used on fishing vessels but so far has been unsuccessful. The investigations seem to be rather prospective since they will not only find application in the telemetering control equipment but will also facilitate the design of controlled trawls and electric power operated fishing gears. The use of electrical cable warps will call for a partial change of the vessel's fishing equipment, including modification of the trawl winches, development of adapter assemblies for connection of the otter boards, installation of various transmitters, etc.

The hydroacoustic communication channel is more convenient for handling and operating but it has disadvantages which restrict its possibilities: dependence on hydrological and metering arrangements. Considerable difficulties are involved when establishing multi-channel communication through the hydroacoustic channel. Besides, the use of a hydroacoustic communication channel in the telemetering equipment which monitors the performance of the trawls causes some additional difficulties associated with peculiar conditions of information transmission.

However, up-to-date achievements of radio-electronics make it possible to considerably decrease the disadvantages of the hydroacoustic communication channels and successfully employ them in underwater telemetering equipment.

Telemetering instruments with cable communication

A first success has been gained in this field by the manufacture of a reliable communication cable. There has been worked out apparatus, type ITEK (depth meter, echo sounder type, with cable communication channel) similar to the apparatus used in Germany (Federal Republic), Germany (Democratic Republic), Great Britain and Poland. The only difference between the ITEK type telemetering apparatus and the foreign made "trawl probes" (netsonde) is that the Soviet-made apparatus has a special selector switch which provides for a joint operation of the instrument in the echo sounder and probe mode. When the instrument functions in this mode the sounding pulses and the echo signals are alternately sent to the ship-mounted and trawl-mounted transducers but are registered on one recorder. This makes it possible to have a combined picture of the situation in the region of the ship and in the region of the trawl. However, when interpreting the echograms,

one should bear in mind that the two situations of trawl and ship are displaced in time by the distance between ship and trawl, divided by the speed of trawling.

Another modification of the telemetering apparatus—ITEX-Y intended for joint operation with any fish finding echo sounder or sonar has been made. Presently, such telemetering instruments employ cable, type KIIKO-2, which is a single strand logging armoured cable with the central conductor made of seven copper wires, dia. 0.3 mm ($\frac{1}{64}$ in), with polyethylene insulation. The outer braiding of the cable consists of two layers of round steel zinc-plated wire, dia. 0.8 mm ($\frac{1}{32}$ in). This braiding wound in mutually-perpendicular directions, takes up all mechanical loads and functions as the second conductor of the communication line. The outer diameter of the cable is 6 mm ($\frac{15}{64}$ in). The cable has a breaking strength of 2000 kg (4,400 pounds) and a relatively low attenuation of the electric energy which ensures normal operation of the telemetering equipment. The specified cable meets the requirements of operation under adverse sea-water conditions and has a long service life. A new winch can accommodate more than 2000 m (2200 yd) of cable and has an automated system of cable heave-in and pay-out. The instrument gives a reliable record of the trawling depth even when the trawl is some 600 m (660 yd) above the sea bottom. It further measures the vertical opening of the trawl, provides observations of fish in the mouth and over, or below the trawl depending on the type of transducer installation. Normally the net transducer has no sound shielding and is thus transmitting and receiving simultaneously in two opposite directions, e.g. up and down to obtain additional information (fig 8).

The echo sounder type telemeters with cable communication channels have practically no relative error between trawl depth and fish depth, if both are alternately registered by the same recorder. If the "trawl probe" has its own recorder, the relative measurement error of the two instruments may be also brought to zero as the method of trawl level measurement and the method of school depth are identical.

Fig 8. Echogram of echo sounder type telemeter with a cable communication channel and no sound shielding on the rear side of the net transducer

1 = headline; 2 = fish echo-traces between headline and footrope; 3 = footrope; 4 = bottom trace; 5 = surface trace obtained with the unshielded rear side of the net transducer; 6 = double bottom echo; 7 = bottom trace in true depth; 8 = echogram of fish which sank under the footrope at the approach of the trawl; 9 = bottom echogram made with ship mounted transducer

Use of telemetering instruments of echo sounder type with cable communication

Synchronous hydroacoustic observations of fish located under the ship's keel and in the trawl zone have made it possible to accumulate valuable material on distribution and behaviour of fish. These observations show that control apparatus, type ITEK and ITEK-Y may be employed for estimating the possible results of trawling by reference to the records and indications of fish between the headline and footrope. The most suitable for this purpose is the C.R.T. indicator which displays a continuous echo signal from the footrope This echo signal may be used as a standard. The comparison of the amplitude of the echo signals from the fish entering the trawl with this standard echo displayed on the C.R.T. makes it possible to estimate the density of fish in the net opening.

This method cannot always be used because of behaviour characteristics of fish in the opening of the trawl. In some cases fish located between headline and footrope immediately enter the trawl so that the records of the shapes of the school obtained from the ship-mounted and trawl-mounted transducers were almost identical; in other cases the fish remained in the net opening for some time so that the trawl-mounted transducer recorded the presence of fish continuously, e.g. up to 30 min whereas the ship-mounted equipment had registered this school only for one or two minutes.

Such behaviour depends on the kind of fish and on their biological state. For instance, blue whiting did not display active reaction when entering the trawl whereas herring in some cases behaved passively but in the other cases substantially different. Sometimes fish having entered the trawl later escape. There have been some cases where fish concentrations detected by the ship-mounted echo sounder were not revealed by the telemetering equipment although the trawl was brought exactly to the assigned level. It happened also that fish schools not registered by the ship-mounted echo sounder were detected in the trawl zone.

Multi-transducer telemetering equipment with cable communication

There are cases where a school of fish registered by the ship's echo sounder cannot be picked up by the trawl-mounted transducer although the net is in the correct depth. This is because after the ship passes above the school it may take 10 to 15 min to bring the trawl to this area. During this period there is no news of the fish school since the sonar cannot operate in the aft sector of the ship (due to the severe effect of the wake) and there are also no data on the exact position of the trawl relative to the ship.

The position of the trawl relative to the ship depends on many conditions such as drift, currents, etc. Besides, the fish may move both in a vertical and horizontal direction. Consequently the trawl can easily miss the school.

To correct these drawbacks a multi-channel system has been suggested which provides for determination of the school position relative to the trawl in the direction of its movement after the ship has passed above the fish. The multi-channel system eliminates the lack of information and provides for guidance of the trawl to the fish until they enter the trawl.

The guidance equipment is made up of four ultrasonic transducers which provide alternate information on the situation in front of the trawl in the directions "forward-upward", "forward-downward", "forward-right" and "forward-left" relative to the trajectory of trawl movement (fig 9). There are also two additional vertical transducers, one directed up to check the situation above the trawl and to measure its distance from the surface, and the other directed down—to check the situation below the trawl, to measure its distance from the bottom and to show the opening height of the trawl.

All the transducers are accommodated within a special streamlined housing attached to the headline of the trawl and are alternately actuated by a simple switching arrangement in accordance with commands from the ship. The underwater unit is connected with the ship-mounted equipment by a single strand cable similar to that employed in the ITEK-Y equipment.

The ship-mounted equipment includes transceiving and recording complex, control panel and cable winch. The control panel is to select the proper information channels and give indications of the actuated channel. Calculations of the possible adjustments of trawl position show that the required range of fish detection should be about 500 m (550 yd). The circuitry of this system provides for collection of other information such as temperature, catch rate etc. Tests of the multi-channel system model performed at sea have given positive results. At present an experimental multi-channel system is being tested under actual fishing conditions.

Telemetering control equipment with hydroacoustic communication

There has also been research devoted to the design of telemetering equipment with hydroacoustic communication channels. Instruments measure the trawl depth, with a range of up to 600 m (660 yd) with communication range of up to 1500 m (1650 yd).

There has been developed a multi-parameter apparatus, called the "Leningrad" employing hydroacoustic communication which is intended to monitor the basic characteristics of the trawl (fig 10). This apparatus provides measurement of the following parameters: depth of trawl between 20 to 400 m (22 to 440 yd), vertical opening height of the trawl within 3 to 15 m (3.5 to 16.5 yd), distance between the footrope and the sea bottom within a range of 1 to 30 m (1 to 33 yd), rate of trawl filling with fish (at three points of the codend) and water temperature within a range of 0° to 30°C (32°F to 86°F). The display of the data on the depth of trawl, vertical opening height, distance from the bottom and water temperature is provided by use of digital indicators. The data on trawl filling with fish are displayed by means of light indicators and an audio signalling system, The data on depth of trawl, trawl height and water temperature may also be recorded on echo sounder paper.

Data on the depth of the trawl is provided in the "Leningrad" system by a rheostat-type manometric transmitter whereas information on the trawl vertical height and its distance from the bottom is obtained by echo

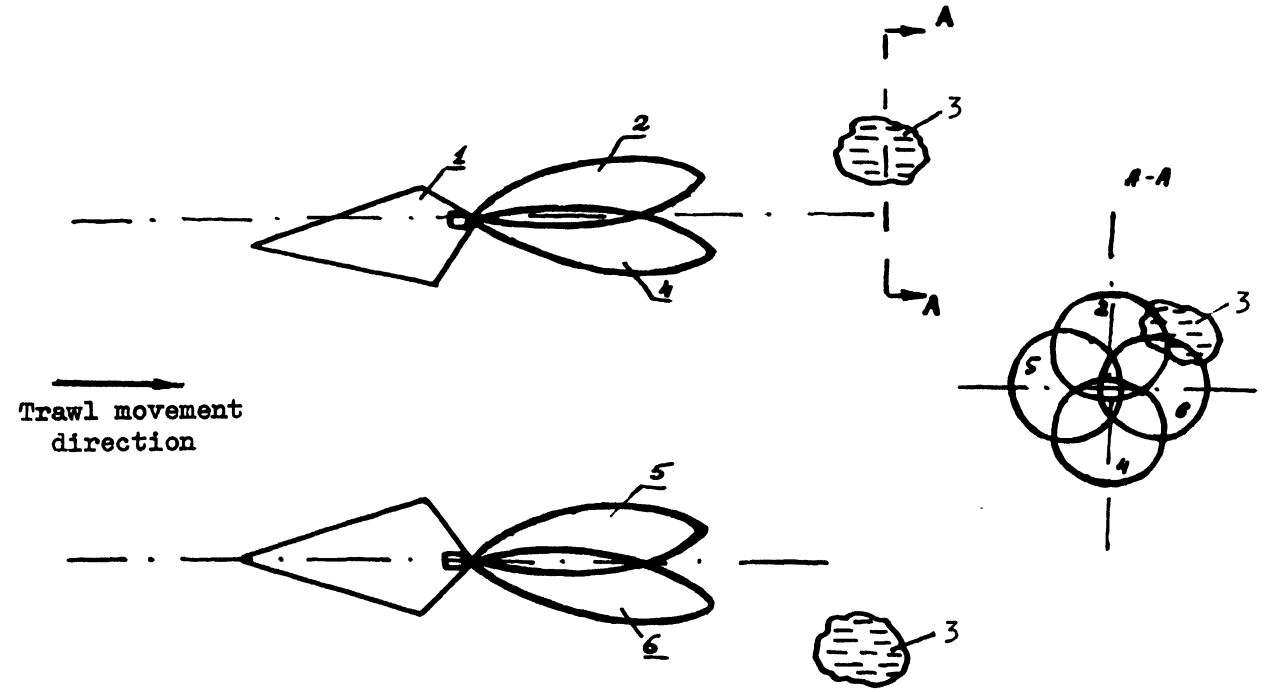

Fig 9. Areas of operation of multichannel telemetric apparatus of trawl approaching a fish school (relative position)
1 = trawl; 2 = "forward-upward" transducer; 3 = fish school; 4 = "forward-downward" transducer; 5 = "forward-to-the-left" transducer; 6 = "forward-to-the-right" transducer

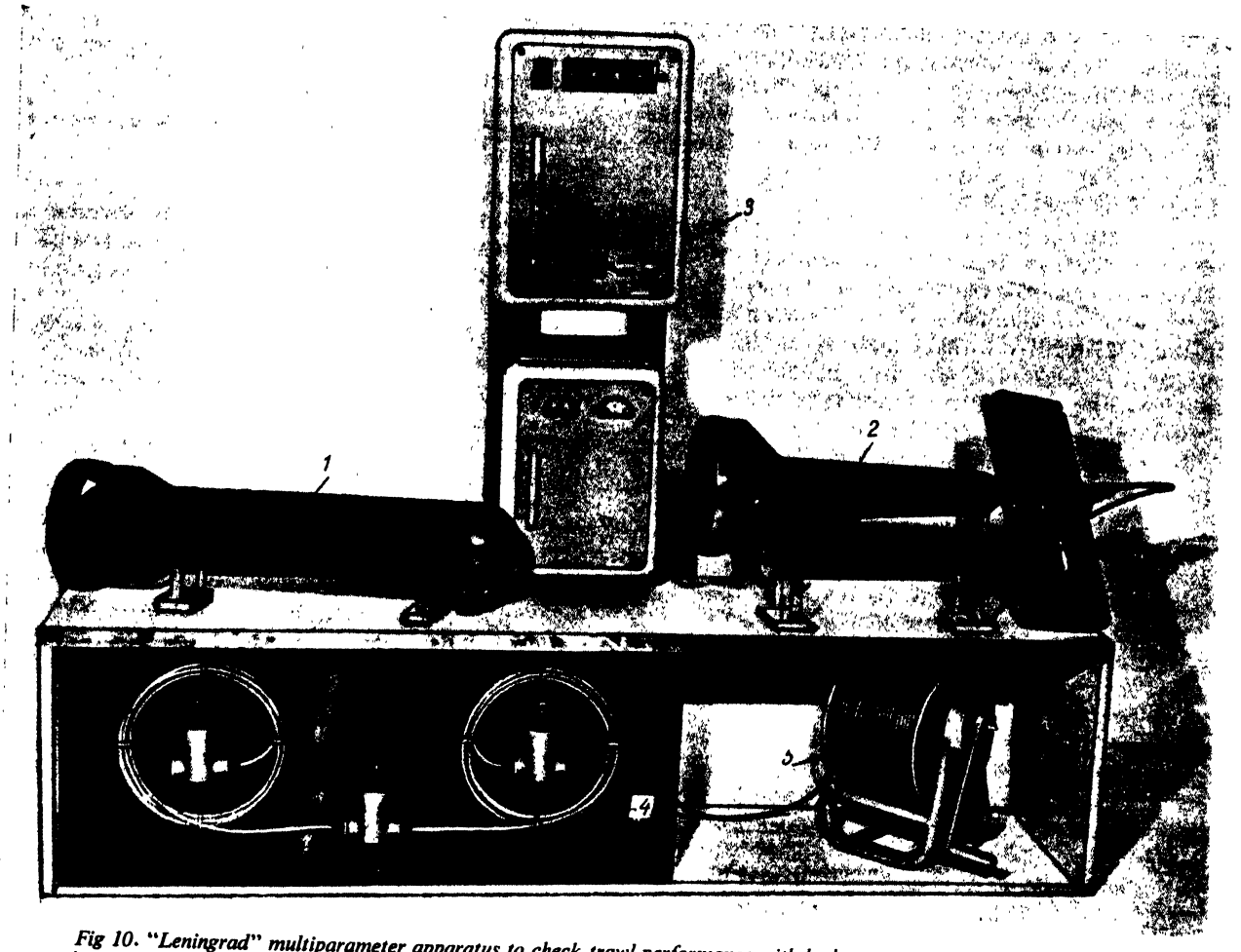

Fig 10. "Leningrad" multiparameter apparatus to check trawl performance with hydroacoustic communication channel 1 = measuring-transmitting device; 2 = reception device; 3 = control and indication panel; 4 = block of fish catch rate transmitters; 5 = cable reel

sounding. Research results show that information on the temperature in the trawl zone helps to determine the movement of fish schools, particularly of those located on the bottom and near the bottom.

Experience gained shows that indications of fish entering the trawl do not always help in determining that the trawl is filling with fish, therefore, special transmitters indicating the trawl filling with fish have been designed and are included in the "Leningrad" system. A simplified method of measurement has been employed: three dynamometric transmitters with microswitches. The transmitters measure the mechanical loads as the trawl fills with fish. They are attached by slings and clamps to the top and side topping lifts of the trawl. The length of the slings is so adjusted that the transmitters operate when the trawl net is being radially extended by fish. The transmitters are connected to each other and to the transmitting assembly mounted on the trawlhead rope by a strong single-strand cable, with the outer braiding made of two layers of steel wire. The breaking strength of the cable is 2 T (4400 pounds). The ranges of the degree of trawl filling are adjusted by displacing the transmitters relative to each other.

The signals from the trawl are received by a hydrophone which is towed off the stern of the ship to reduce the noise level. Then, the information is transmitted to the monitoring and display unit where it is interpreted and registed. To ensure transmission of information from several transmitters, the channels are separated in time.

Sea tests of the equipment carried out on a trawler employing midwater and bottom trawls have brought positive results.

At present wireless telemeters employing hydroacoustic communication channels are being developed and improved very rapidly. This development, which began with the design of simple depth telemeters for trawls, has lead to various types of multi-parameter and multi-channel equipment which feature an ever-growing range of operation, reliable communication and having wide measurement limits.

Impact of Technology on Performance of New Fish Detection Equipment

S. Mross, H. Purnhagen

La technologie et son impact sur les performances et la definition des nouveaux equipments de detection du poisson pour le chalutage hauturier

Depuis 1960 il est apparu de plus évident que les anciennes techniques électro-mécaniques et de tubes à vide présentaient un handicap sérieux pour l'obtention d'un progrès substantiel dans la détection du poisson par écho-sondage. Outre la sécurité de fonctionnement, le patron de pêche a besoin d'informations plus détaillées afin de prendre de meilleures décisions au cours des opérations de pêche. Pour servir de base à des innovations sensationnelles dans les performances, l'information et la prise de décisions l'utilisation conséquente de la technologie électronique et hydro-acoustique la plus moderne est une nécessité. Des améliorations quantitatives considérables de performances, de définition et de tolérances sur les systèmes secondaires sont possibles. De nouveaux concepts et particularités peuvent maintenant être obtenus avec un matériel de faible volume, de rapport prix/performances considérablement amélioré et une sécurité de fonctionnement très élevée. Pour illustrer ceci on passe en revue la technologie actuelle de l'oscillateur et les composants analogiques et digitaux en électronique compacte, y compris les circuits intégrés, en considération de leur application possible à la détection du poisson. Un nouveau système de représentation en image continue par tube cathodique et par un système d'enregistrement avec dilatation d'échelle comprenant une mémoire digitale est maintenant réalisable. Par une modification de la fréquence de déplacement avec les différentes gammes de temps une image constante peur être obtenue. Toutes les améliorations rendues possibles par la nouvelle technologie n'ont toutefois un impact qualitatif sur les performances et la définition qu'à la condition d'être combinées avec une véritable approche du système.

La tecnologia y su repercusión en el funcionamiento y precisión del nuevo equipo de localización de peces para pescar al arrastre en alta mar

Durante el decenio de 1960 se hizo cada vez más claro que las viejas tecnologías electromecánicas y de lámpara de vacío constituían un importante obstáculo para lograr adelantos considerables en la detección de los peces mediante el sondeo por eco. Aparte la seguridad de los datos, el patrón necesitaba información más detallada con objeto de adoptar mejores decisiones en las faenas de pesca. Para crear la base de un nuevo impulso en la actuación, información y adopción de decisiones, constituye una necesidad el uso adecuado de la más moderna tecnología electrónica e hidroacústica. Son posibles considerables mejoras cuantitativas de rendimiento, precisión y tolerancias en los subsistemas. Actualmente se pueden introducir nuevos caracteres y conceptos funcionales con instrumentos de poco volumen, una razón precio/rendimiento mucho mejor y una mayor seguridad. Para ilustrar esto, se examinan con respecto a su aplicación en la localización de peces, la tecnología de los transductores y loscompo nentes electrónicos analógicos y digitales de estado sólido, incluyendo los circuitoa integrados. Se dispone de un nuevo sistema de tubo de rayos catódicos de presentación visual y de un sistema de escala de registro ampliable con memoria digital. Cambiando la frecuencia de desvío según las diferentes series de tiempo, la imagen puede seguir siendo constante. Sin embargo, todos los adelantos hechos posibles por la nueva tecnología tienen un efecto de tipo cualitativo sobre el funcionamiento y la definición únicamente con la forma de funcionar de un sistema real.

THE most severe problem facing the skipper in deep sea trawling remains the acquisition of quantitative and qualitative information about the fish he seeks.

This paper aims to show how the most modern electronic and hydroacoustic technology can achieve this by improvement of subsystems. Further, that the introduction of new functional features and concepts becomes feasible with hardware of low volume, very high reliability and a much better price/performance ratio.

TRANSDUCER TECHNOLOGY

For almost 40 years the magnetostrictive laminated stack transducer has been the most commonly used sound-generating element in echo sounding. Despite its simplicity and good aptitude there are serious disadvantages such as poor overall efficiency of 10 to 20 per cent, its strong dependence on the state of polarization, and in particular tolerances and reproducibility problems associated with heat treatment, assembling, grinding, etc.

Today's most advanced transducer technology is based on the electrostrictive polychrystalline ceramic. Commonly known as "barium-titanate", this material has been used for years in the form of disks operating in the so-called thickness mode in transducers for high frequency echo sounders.

Transducers based on such developments (fig 1) are cheap and have a high efficiency of about 40 to 50 per cent. Yet there are limitations with respect to frequency, power and beam width. But these technical disadvantages of barium titanate are almost completely overcome by new compositions known as "Lead Zirkonate-Titanate (PZT)". The Curie temperature of these are between 250° and 400°C, the internal losses are very low, and the coupling coefficient of 0.7 is among the highest obtained

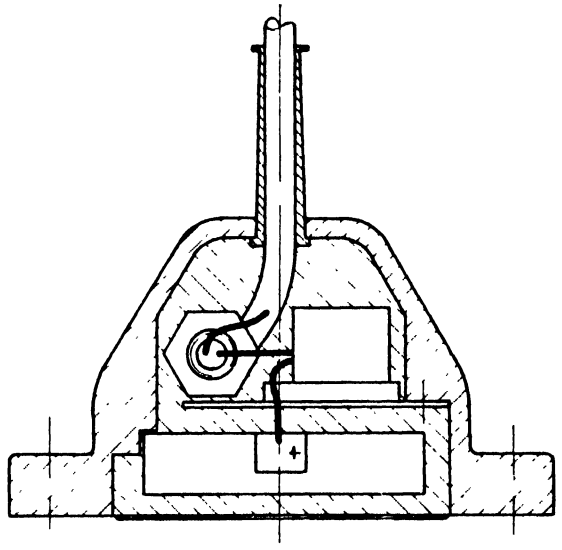

Fig 1. Epoxy covered "thickness mode" 200 kHz transducer with a disc of barium titanate

so far. These properties of the PZT-Ceramics promoted considerable advance in the technology of compounded transducer elements, in which metallic pieces are bonded to the active disk. Thus not only lower frequencies can be obtained, but also important transducer characteristics such as intensity, efficiency, bandwidth, beamwidth, etc. can be largely influenced by the designer.

High intensity transducers recently introduced use mechanical biased, compounded PZT transducer technology (fig 2) to obtain elements with convenient dimensions, great uniformity, and reproducibility in quantity manufacturing.

This is important for building transducer arrays with the accuracy needed for beam forming and beam switching techniques. Figure 3 shows such a transducer array in a common plastic housing. It consists of 19 elements of which either the 7 inner elements, forming a beam of 19°, or all 19 elements with a 10° beam can be used. With such a transducer the definition can be considerably improved by tapering the amplitudes of the elements or building transducer groups within the array. By the first method the side lobe pattern can be improved; the second allows exploitation of phase information of received fish echoes in order to determine the exact location of fish within the searching beam.

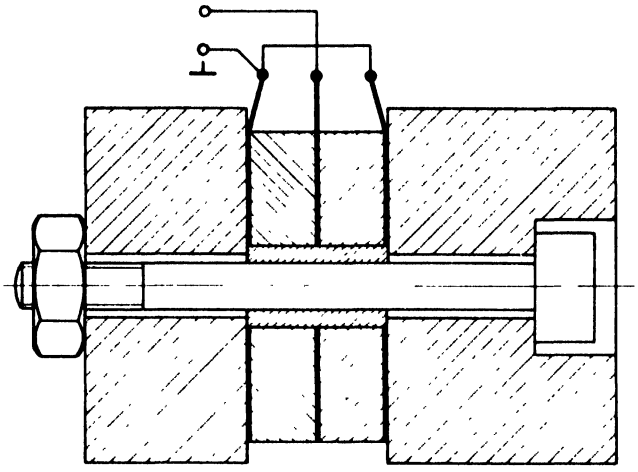

Fig 2. Mechanical biased compounded PZT-transducer element as used in latest high performance transducer arrays

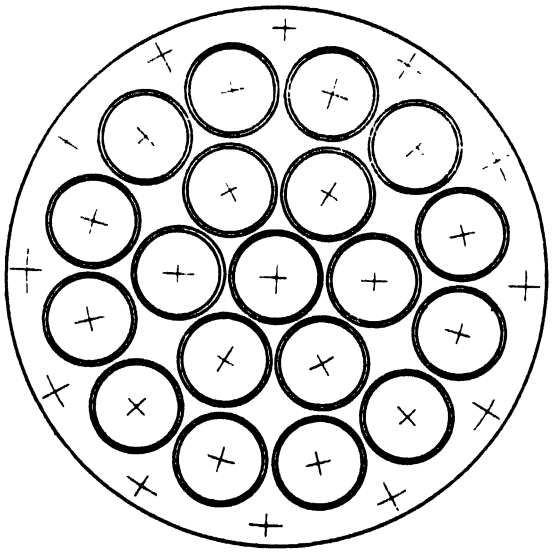

Fig 3. Array configuration of a 33 kHz transducer with beam switching and beam forming possibilities

ELECTRONIC COMPONENTS

The tremendous progress in electronic technology of the last decade started with the invention of the transistor about 20 years ago. In middle 1960's, the first partly transistorized echo sounders were introduced. Germanium transistors replaced tubes in the amplifier. Transistorized transmitter power stages were not feasible, for the maximum crystal temperature of the germanium transistors was limited to about 90°C.

Silicon transistors with their upper temperature limit of about 200°C represented an important improvement. The planar process of fabrication led to high reliability and low costs. Then it was possible to use more transistors and to develop new circuits in which the transistors not only replaced the tubes previously used; transistorized transmitter output stages with high power became feasible. New elements like the zener diode, which acts as a voltage stabilizer, and the silicon controlled rectifier, a diode, which can be switched on by a pulse, were produced and led to new circuit concepts.

In the meantime the silicon planar process was improved further. Now complete circuits with many transistors and resistors can be produced on one silicon chip.

These integrated circuits (IC) led to even higher reliability of equipment because of the reduced number of soldering connections. Since the fabrication of such circuits differs only slightly from those of a single transistor, the cost (after a period of introduction) could be kept low. Prices have fallen drastically in the last few years, so that the IC's now enter the "price-oriented" commercial market.

One of the latest developments in transistor technology is the MOS (Metal Oxide Silicon) transistor, which is also produced by the planar process. In this the output is controlled by an input voltage as in a tube and not by an input current. These MOS transistors need much less space on a silicon chip, so that it is now possible to get more than 500 transistors on a chip of 1 mm^2 (0.0015 sq in). Only with IC's of this type can such systems as the steady picture display or the recording scale expander be developed and produced at reasonable cost.

The heart of these systems is a static MOS shift register, a circuit, which can store digital information for a predetermined time. It consists for example of 100 storage elements made of 8 MOS transistors each, which are connected together like a chain, so that only few input and output connections are needed. Each time a control signal (clock) is applied to the storage elements, the digital information stored in each element is shifted to the next one (see fig 4). The first element stores the new input signal and at the output of the last element appears the input signal applied 100 clock steps before. With the next clock pulse, the information is shifted one step further and so on.

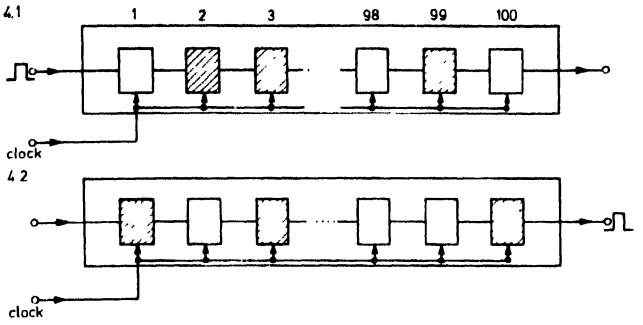

Fig 4. Shift register principle

With these MOS shift registers, the echo information can be stored and reproduced at a time more convenient for the display system. Since the time interval between two clock pulses can be varied electrically, the display of the stored information can be made faster or slower than the input of the information and is no longer restricted to "real time" conditions. By this special feature new functional concepts can be introduced now into fish detection equipment.

ANALOG CIRCUITS

An analog circuit used in all fish detection equipment is the amplifier. By the consequent use of transistors it is now possible to build for commercial applications high performance amplifiers with stable and reproducible characteristics restricted until now to scientific or military equipment.

The small signal gain of a transistor can be altered by varying the direct current through it. By controlling this current by another transistor the gain becomes a logarithmic function of the control voltage (fig 5), i.e.

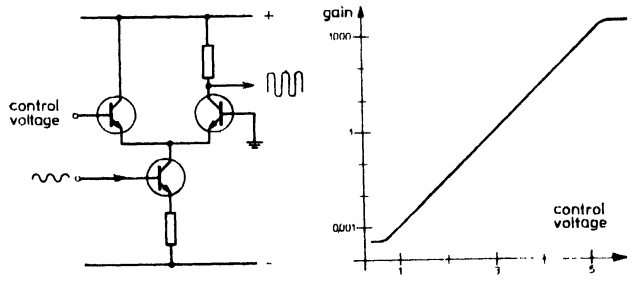

Fig 5. Transistorized gain control stage with linear logarithmic characteristic

the gain of the stage doubles at each constant increase of the control voltage. Gain variations up to 1:1,000,000 (120 dB) are feasible with this concept.

Since the mechanism of the gain control depends on the physical structure of the transistors only, tight tolerances of the characteristic are achieved with each production unit even over a wide range of ambient temperatures. Due to this uniformity of the gain control characteristic, reliable time-volume control can now be achieved by simple means.

Essential for definition is furthermore undistorted dynamic processing of short echo pulses, as from single fish. Time distortions influencing the radial definition occur heavily in all amplifiers which use several LC-tuning circuits in order to economize tubes or transistors. These can partly be overcome by the application of RC-coupling between the amplifier stages and the use of balanced gain control stages of the above mentioned type, now available as IC's. But with the heavy overdriving of the circuit, which happens at least during transmitting, even with RC-coupling distortions can be considerable due to capacity recharging and rectifying effects of transistors. These difficult problems, the solution of which finally determines the performance quality of an echo sounding amplifier, are to be solved by a careful application of the latest circuit theory employing direct coupled complementary transistors or integrated circuits.

Bottom discrimination

The "grey line" or "white line" facility is accomplished by switching the output of the recording amplifier to grey or white if the high amplitude sea-bed echoes exceed a fixed or manually adjusted threshold voltage. With printed circuits and cheap transistors it is now possible to use more sophisticated circuits in which the threshold is automatically adapted to the changing magnitude of the echoes received from the bottom. This assures that echoes from demersal fish are under all detection conditions definitely separated from bottom echoes.

In the circuit, shown in fig 6, the output of the gain and time control stage of the amplifier is connected to a peak rectifier followed by an integrating circuit. The output voltage obtained corresponds to the changing mean

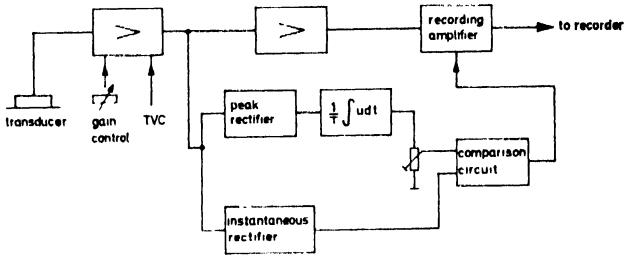

Fig 6. Bottom discrimination circuit with automatic threshold adaptation

value of the bottom echo amplitude, which depends for example on the depth and structure of the sea bed. If the instantaneous echo voltage which is measured by another rectifier exceeds a predetermined fixed fraction of this voltage, an output signal is emitted by a comparison circuit to the recording amplifier. By this, the threshold is automatically adapted to the changing bottom echo amplitude and does not need to be readjusted. Circuits of this type could not be used with conventional vacuum tube techniques because of the great number of active elements needed.

Motor speed control

The speed control of the motor which drives the recording device is still another example of the impact of modern technology. Previously, in most cases either a synchronous type of motor, which depended on the stability of

the electrical supply, or a motor with a governor was used. Now, electronic speed regulation systems are feasible with far better accuracy and long term stability.

In the advanced system a toothed wheel is scanned magnetically so that at each revolution of the motor a magnetic pickup produces electric pulses proportional to the number of teeth on the wheel. The motor speed is thus measured by the frequency, which is converted into a DC-voltage and compared with the stable voltage of a zener diode.

The difference between these two voltages is amplified and controls the supply voltage of the motor and consequently its speed. By using a wheel with a lot of teeth and a sensitive frequency discrimination circuit, accuracies up to 0.2 per cent can be obtained without great difficulties. A change of speed, necessary when switching the basic ranges of the echo sounder can easily be obtained by dividing the pulse frequency electronically before converting it into DC.

This motor speed regulation enables an easy connection of digital circuits, such as digital depth displays, since the frequency of the motor pulses can be chosen so that the time between two pulses equals, for example, 1 m of depth. If an electronic counter connected to this frequency is started by the transmitting pulse and stopped by the bottom echo pulse, the number of pulses counted equals the depth of the bottom. Since the number of pulses during one revolution of the recording stylus is fixed, these pulses can also be used to indicate the momentary position of the stylus referred to a starting point, say the zero line. This fact is used in the recording scale expander described later.

DIGITAL STEADY PICTURE DISPLAY

A cathode ray tube display is being used in most deep sea trawlers for the exact evaluation of echo amplitudes in order to recognize the density of schools and to distinguish fish above the sea bed. Since the scope must be operated for periods of hours, there is considerable strain on the operator from the flashing nature of the display. These drawbacks have been overcome by a "steady picture" display achieved by means of a magnetic recording drum, which stores the echoes of fish near the sea bed. The echoes can be replayed many times during each sounding cycle, thus giving a continuously bright picture on the scope.

Another element for steady picture display is the direct view storage tube now used in modern aircraft radar systems and oscilloscopes. With these the persistence characteristic of the screen can be controlled electronically and extended from milliseconds like in conventional CRT's up to minutes and hours. By carefully adjusting the persistence, the echoes from the previous sounding cycle can still be seen when the new echo appears, thus resulting in a continuous picture. The persistence of the direct view storage tube, however, depends strongly on the desired brilliance. This calls for a readjustment of the controls if measuring range or brilliance have been changed. Prices of larger storage tubes, e.g. 7 in (18 cm) until now have been very high and have prevented the use of such tubes in fish finding.

Now a new system of steady picture display has become possible by using high capacity MOS-shift registers. These can be used to form a digital recirculating memory with some important new features.

A complete system is shown in fig 7. The echo signal present at the input is rectified and the resulting DC-voltage digitized by an analog/digital converter. In order not to lose any information present in the input signal, the number of discrete amplitude steps as well as time steps has to be high. Values of at least 200 time steps and 50 amplitude steps are necessary with a 7 in CRT. The digitized information now is fed via an electronic switch into the MOS-shift registers. When the recording is finished, the electronic switch changes to the replay position. The digital echo information stored in the shift

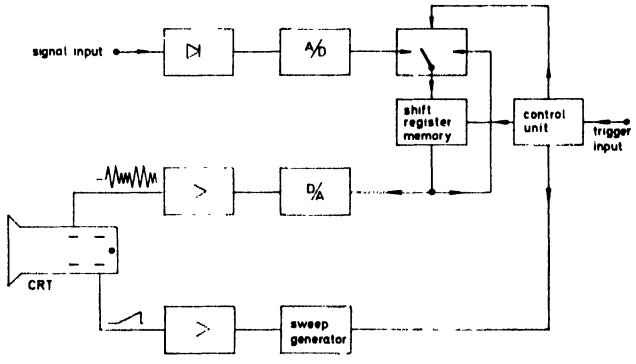

Fig 7. Block diagram of a digital steady picture CRT display

register is reconverted into an analog signal and displayed on a conventional CRT. At the same time, the digital output signal is fed back into the shift registers to preserve the information. So after one sweep is finished, the original information is still present. By replaying the stored echo information many times during each sounding cycle, a steady picture can be obtained on the CRT.

One main advantage of such a system is the fact that the replay time is no longer restricted to the "real time" conditions due to the electronically controllable shift frequency. It is possible just by increasing the shift frequency by a factor of 10 during replay to display in 13 msec a 100 m (55 fm) survey range which has been recorded in 133 msec. With a storage system only capable of working in real time, the replay time would have been also 133 msec, thus resulting in a picture frequency of about 7 cycles and severe flickering of the CRT-display.

Rapid progress in developing and producing semiconductors in recent years has enabled new concepts like the above to become possible. The heart of this system, the digital recirculating memory capable of storing more than 1500 bits of information, consists of only six tiny IC's similar to transistors. The extensive analog/digital and digital/analog converters needed, can be realized by other IC's developed recently. Since prices of integrated circuits are still falling considerably, sophisticated systems like this one can now be introduced with hardware of low volume, far better price/performance ratio and high reliability.

RECORDING SCALE EXPANDER

A recording scale expander records small depth ranges on large scale paper. It can be employed in survey systems, working in shallow waters, and in fish detection equipment especially suited for recording fish near the sea bed or within the trawl opening. In recording scale expanders known until now, the speed of the stylus has been increased according to the small measuring range. This has resulted in some mechanical difficulties, especially when a start-stop moving of the stylus is applied, as is necessary when recording the sea bed as a straight line.

Recently, a new system has been introduced using a fixed comb-like array of styluses. In this "multistylus" recorder the styluses are scanned electrically. Since the writing stylus can be moved electrically rather than mechanically, considerably increased writing speed is possible and start-stop can be applied easily. To get high resolution, however, it is necessary to make the styluses as thin as possible and to minimize separation. This presents a difficulty, but with the introduction of high capacity MOS-shift registers a new promising concept for a scale expander working with a conventional recorder has become feasible. In this concept the shift register is used as a memory and as a time expanding device. The system consists mainly of a recorder with a motor speed control employing a frequency generator a shift register with A/D and D/A converters and a common control unit. The echo signals of e.g. a 5 m (16 ft) depth range are digitized, stored in the shift register and replayed later on the recorder working with a slow stylus speed corresponding e.g. to a 100 m (55 fm) basic range. As the number of positions (bits) in the memory used per unit paper width can be chosen at any desired value, the resolution up to the smallest ranges is limited by the properties of the recording paper only.

A scale expanding system of this kind has many advantages. The ratio of the time expansion can be easily and accurately varied by switching of an electronic oscillator.

High resolution recordings on dry paper can be obtained by use of high capacity shift registers. The mechanical start-stop moving of the stylus needed previously to obtain a sea-bed-locked display can be replaced by a proper electric start-stop control of the shift register. Even stylus wear no longer presents a problem, if a keying system actuated by the stylus itself is used.

SYSTEM APPROACH

Today's electro-acoustic and electronic technologies offer a lot of new possibilities for the development of new fish detection equipment. In this situation the system engineer becomes more and more important. A comprehensive application study will be necessary covering different fishing techniques and fishing ground conditions, since these have to be regarded as part of the environmental conditions of the system. At the start of the system-design process it will be very important to define carefully the purpose and a set of optimum outputs in order to obtain a proper integrity of the system. Unfortunately, this integrity and the systems view point seem to be not yet generally achieved in fish detection. A receiving channel for example with excellent echo processing will do little for the performance of the system if used together with a poor transducer or small recording paper with poor resolution. Thus the design must deal with the components and subsystems in such a way as to optimize the overall system. In fish detection this will be done mainly around the following view points:

Reliability, where, among others, component testing and selection will be very important.
Cost/effectiveness, which implies the application of value engineering methods in all stages of development and design.
Information.

Information is the common purpose of a fish detection equipment and to that end all parts have to contribute.

The main optimization effort has therefore to take care of the best possible information flow from the target through all parts of the system to the display. By a consequent use of modern technology's possibilities along these lines of system design, an impressive impact on performance and information quality can be achieved, as the experience with some newly introduced equipment shows.

But this is not enough. The information has to be transfered to the human brain, where decisions have to be made. All concerned with fish detection equipment know about these difficulties, and a great effort is being made to teach skippers how to utilize equipment more effectively.

There seems to be a demand for the engineer to consider more closely fish detection as a man-machine information system in which human information-processing factors play a very important part. It can be shown that a number of problems in the man-machine interface could be better solved by a more complete application of human engineering principles. The kind, specifications and locations of various displays can be influenced accordingly by the engineer as well as the philosophy of operation, where logical linkage and automation of operational variables can reduce the number of controls.

As men will continue to play an active role even in tomorrow's automated fishing systems, more and effective instructions of operators will be necessary. All technical progress, however it may be enjoyed, cannot eliminate the fact that the perfect technical system does not exist.

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Research on Telesounders (Wireless Remote Control Echo Sounding)

T. Hashimoto, Y. Maniwa, M. Kato

Recherche sur les telesondeurs (Echo-sondage telecommande par radio)

On a mis au point, pour transmettre à distance par ondes radio des échogrammes de bancs de poisson, un appareil de télésondage susceptible d'utilisation dans la pêche commerciale. Cet appareil peut recueillir et transmettre à une base centrale des renseignements sur les bancs de poissons que les bateaux chargés du repérage ont détactés. Un patron pêcheur peut ainsi analyser les échogrammes et diriger les opérations de la flotte de pêche de manière plus efficace. De plus, cet appareil est utilisé dans la pêche aux filets fixes (pièges) pour déterminer la quantité de poissons qui pénétrent dans les filets.

Investigaciones de teleecosondas (telesondeo acustico inalambrico)

Con vistas a su posible empleo en la pesca comercial se ha preparado una teleecosonda que mediante ondas hertzianas permite transmitir ecogramas de cardúmenes de peces a un lugar distante. El aparato en cuestión puede recoger y transmitir a una base central la información sobre los cardúmenes de peces obtenida por las embarcaciones dedicadas a la localización de los mismos. De esa forma, un jefe de pesca puede analizar los ecogramas y dirigir más eficazmente las operaciones. Además, el aparato es útil para la pesca con redes fijas (trampas), porque permite determinar el número de peces que entran en ellas.

IF it were possible for purse seiners to receive, via radio, echograms of concentrations of fish from several fish finding boats, a chief fisherman could direct the vessel's operations accordingly, and the efficiency of purse seining might be greatly improved. With stationary net fishing (traps) an anchored, remote echo sounder-radio transmitter device could provide information on the quantity of fish entering the net. An electronic system to accomplish these objectives has been constructed and tested to demonstrate its utility. It was named "Telesounder". In this paper only the buoy device used in conjunction with the stationary net is described; however, the system should have application in the purse seine fisheries.

TRIAL PRODUCTION TELESOUNDER

A block diagram of the experimental Telesounder is shown in fig 1. The circuit is completely transistorized and compact. The echo sounder recorder was located at a base station and the echo sounder transmitter-receiver was mounted at a buoy station.

The 42MHz frequency-modulated (FM) pulses used to control the buoy station, are emitted from the transmitter (T_1). The receiver (R_1), which is placed in a distant location, receives signals from the transmitter which

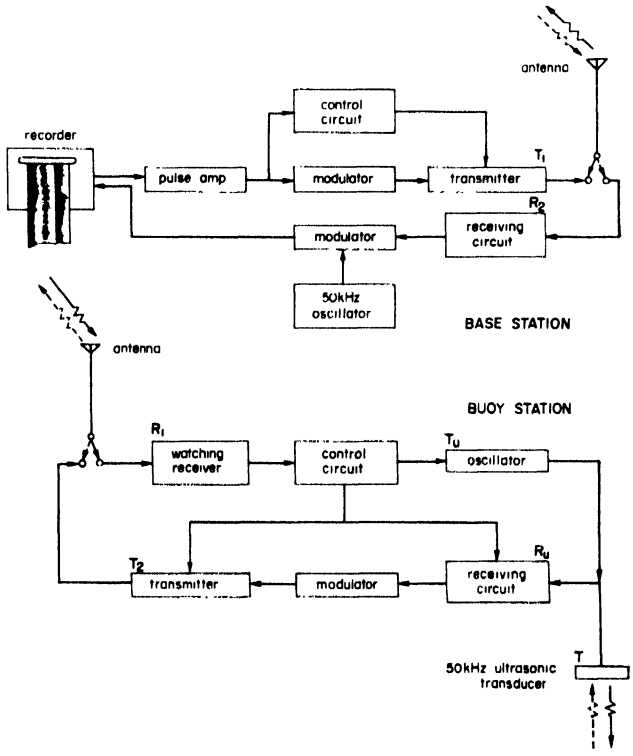

Fig 1. Block diagram of Telesounder system

motivates the ultrasonic oscillator (T_u), and the transducer (T) in turn emits a 50kHz ultrasonic pulse. The echoes returning from the sea bottom and fish schools are received by the transducer, and amplified by the ultrasonic receiver (R_u). The 42 MHz radio waves which are frequency-modulated by these echo signals are then transmitted (T_2) to the base station's receiver (R_2) where the echo signals to be recorded are electronically screened out from the carrier wave.

FM transmission was used for reliability and good signal to noise ratio. The echo sounding transmitter-receiver and the FM transmitter at the buoy station are turned on when the FM receiver receives pulsed signals from the base station. The buoy station consumes only a small amount of electric power, since only the FM radio receiver is working when there is no signal from the base station.

The transmitting power of the echo sounder transducer is 15 W. Fig. 2 shows the buoy, in which the electronic instruments are installed.

Fig 2. Telesounder. Buoy in which the electronic instruments are installed

EXPERIMENTAL TESTS

The initial experiment using the telesounder was carried out in October 1962 off the Kurihama coast of Yokosuka by using two boats and the equipment was a 2.6 MHz radio transmitter and receiver, and a 200 kHz fish finder. Their construction is almost the same as shown in fig 1. During the experiment a 400 kHz fish finder was also used and its recordings were compared with those obtained using the Telesounder at a distance of 2,000 m. Fish schools and the sea bottom were clearly indicated by each piece of equipment.

As a result, additional experiments were made at Izu Ajiro in March 1963 using a prototype production model Telesounder. Two boats were used. The base station for the Telesounder and a standard 50 kHz fish finder were installed on one boat, and the buoy station was installed on the other. The two boats ran on exactly the same course, operating both equipments at the same time. Fig 3(a) is the record of the Telesounder and fig 3(b) is that of the 50 kHz fish finder. A, B and C in the figure are their relative positions. The spots on the figures are mutual interference by the 50 kHz echo sounders. It was shown that the Telesounder could obtain the same kind of recordings as an ordinary fish finder. It was also feasible to transmit echoes from a distance of 4,000 m.

In the second stage of the experiment the recorder was placed on land, and the buoy station was placed at a stationary net at a distance of 3,500 m. Fig 4 shows fish schools passing under the transducer of the buoy station.

Fig 3. Echo traces recorded by Telesounder (a) and by 50 kHz fish finder (b)

Fig 4. Echo traces of fish schools entering a stationary net (transmitted by Telesounder)

Sound Beam Stabilization for Echo Sounding and Sonar

J. Miyajima

Stabilisation du faisceau acoustique pour l'echo-sondage et le sonar

Les besoins en dispositifs ultrasonores sous-marins se sont accentués au cours de ces dernières années. Les demandes pour une localisation plus précise du poisson, pour une meilleure discrimination des caractéristiques des objectifs et pour des appareils de mesure de la vitesse sur le fond par Doppler de précision élevée (±5 cm/s) rendent indispensable la stabilisation en direction et en intensité des faisceaux acoustiques ultrasonores. Des exemples pratiques apportant une solution à deux de ces problèmes sont discutés.

Estabilización del haz sonoro de los ecosondas y del sonar

En estos años se están haciendo cada vez más acuciantes las necesidades de intrumentos ultrasónicos submarinos. La exigencia de una más precisa localización de los peces, mayor discriminación de las características de los blancos, y la determinación de la velocidad sobre el terreno del efecto Doppler de gran precisión (± 5 cm/s) requieren una estabilización direccional y de intensidad de los rayos ultrasónicos. Se examinan ejemplos prácticos para la solución de dos de estos problemas.

SONAR beam stabilization is necessary to improve the location of targets. Sonar beams change their direction due to the motion of the vessel, i.e. roll, pitch and yaw (fig 1). Beam direction can be controlled automatically with a control system (fig 2) of training (horizontal) and tilting (vertical) consisting of:

ϕ_r Detect: Detector of roll (angle around the fore-aft axis of the ship). Pendulum (cheap) or Gyro device (expensive).

ϕ_p Detect: Detector of pitch (angle around central port-starboard axis of the ship). Pendulum or Gyro device.

ϕ_y Detect: Detector of yaw (angle around perpendicular axis of the ship). Gyro device.

$\Delta\theta_t$, $\Delta\theta_d$ Convert: Converts deviation angle of ϕ_r or ϕ_p or ϕ_y to component $\Delta\theta_t$ and $\Delta\theta_d$. $\Delta\theta_t$ differential component angle of training. $\Delta\theta_d$ differential component angle of tilting.

Synth.: Synthesizes each $\Delta\theta_t$ or $\Delta\theta_d$ which comes from ϕ_r and ϕ_p and ϕ_y.

θ_t, θ_d Reg.: Regulator of training and tilting of sonar transducer. Electro-mechanical servo device or hydraulic servo device. Depression of mechanical vibration and electrical induction into the transducer should be provided.

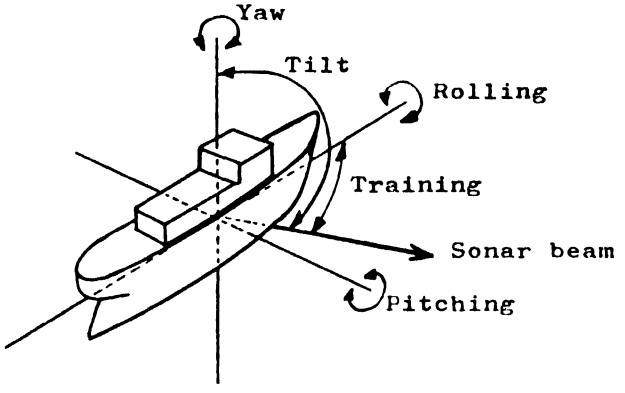

Fig 1. Reference between training, tilting and roll, pitch, yaw.

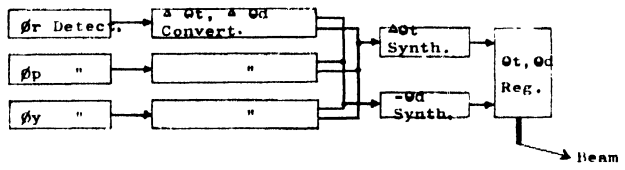

Fig 2. Block diagram of automatic stabilizer

BEAM REGULATOR

The most popular device to stabilize sonar beams is electro-mechanical control of the transducer. It is not in continuous operation, but accentuated by electric impulses for training and/or titling as required. The electric impulses, however, induce noise in the receiving amplifier. Automatic beam stabilizing against minor motions of the ship needs a quick sequence of control operations and the electric noises may then reduce the utility of the sonar.

Mechanical vibration of the training and tilting mechanism is transmitted through the training shaft or tilting lever to the transducer and also generates electric noise. These noises should be eliminated by careful design and workmanship.

Mechanical servo devices need some increment of time operation. Too quick a response induces hunting of the system. The response time must therefore be set carefully with regard to the time intervals of the detector and the motions of the ship under various sea states.

Direct beam regulation with electronic circuits is superior to mechanical regulators as they are not subject to inertia. Electronic regulators control the directivity of the sound beam by varying unit intensity and phase of the acoustic signal at the face of the transducer. Deviations in directivity due to the motion of the ship is compensated by respective changes of intensity and phase of the electric signal of each transducer unit. Directivity regulation units of these types are available in practical design (fig 3).

The transducer assembly consists of 2n−1 units of none directivity arranged on a straight line in the distance l. Natural main directivity of this transducer assembly with uniform input or output is shown in fig 3.

Input or output of each unit transducer is regulated according to the following equation:

$\Delta\omega_n = 2\pi\, nl \sin \Delta\theta_d/\lambda$

$\Delta\omega_n$ = phase angle to be regulated for each unit

$\Delta\phi_d$ = angle of main directivity to be regulated

λ = wave length of acoustic signal

l = distance between each unit transducer

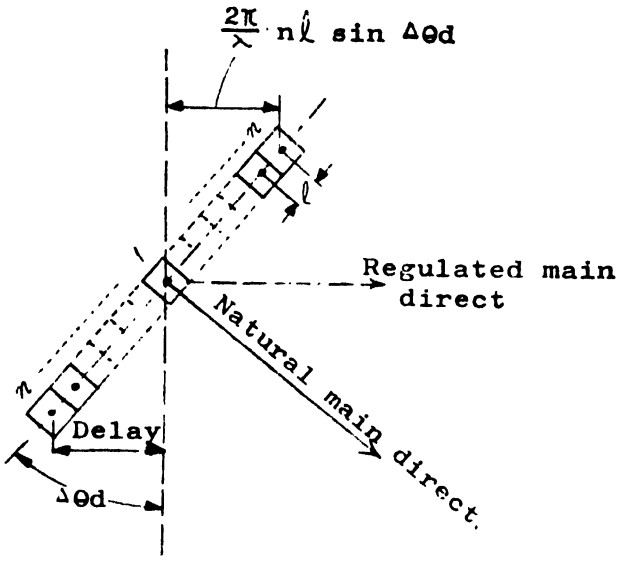

Fig 3. Reference for mechanical angle and acoustic phase

The directivity of any transducer assembly composed of units and arranged in a plane can be regulated in this way.

Phase regulation of acoustic signals of transducer units is available using electronic circuits combined with unit transducers. Phase regulation of electronic circuits is accomplished by changing the values of electronic components. These components are available in low power transmission. High power components are big in volume and expensive. Systems with regulated wide beam transmission and regulated narrow beam receiving are therefore not economical.

MECHANICAL STABILIZATION OF ECHO SOUNDERS AND BOTTOM SPEED METERS

Contour maps for dredging require an accuracy of centimeters in depth because the amount to be dredged up may be very large for every centimeter if a large area is involved. Dredging costs depend directly upon the volume to be dredged up. Quotations of dredging expense are determined by contour maps obtained with depth recorders which therefore must be extremely accurate. Echo sounders always record the most shallow point within the effective beam for every sounding. Wide beam sounding may cause large errors over irregular grounds, although deviations in the direction of the beam have no influence. Narrow beam sounding gives good results but deviations in the direction of the beam are critical and could cause errors similar to wide beam sounding. If the angle of deviation is constant and known, the correct depth can be calculated (fig 4).

Narrow beam echo sounders with mechanical directivity stabilizations (Gymbal suspension) are available (figs 5 and 6).

This assembly is mounted in a sonar dome filled with a fluid which has low sound absorption and proper viscosity to give critical dampening of oscillation and

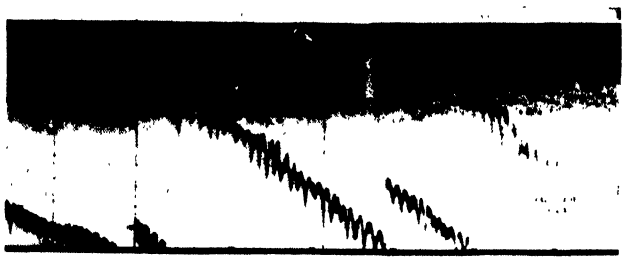

Fig 4. Depth record of narrow beam echo sounder

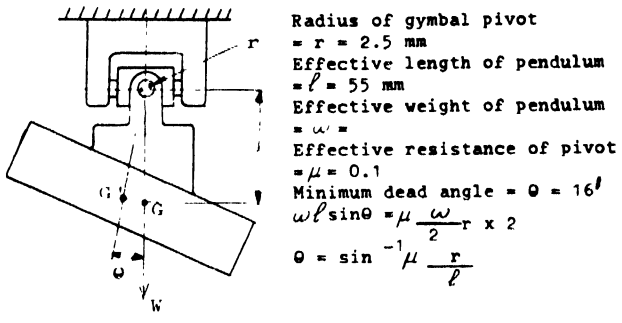

Fig 5. Principle of gymbal suspension

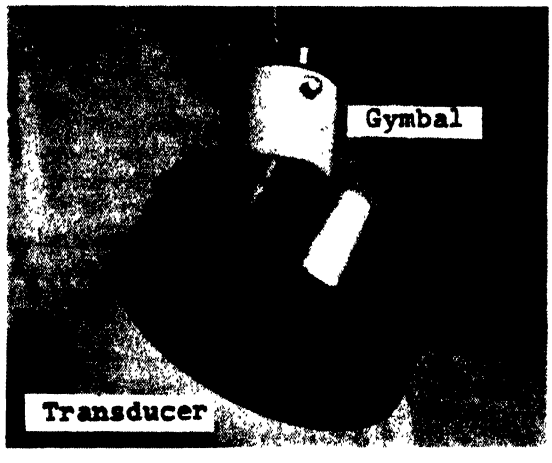

Fig 6. Transducer with gymbal suspension

restorative velocity of the pendulum. Viscosity of the fluid is selected to give maximum restorative velocity when the pendulum shifts away from neutral position.

Ground speed meters have two sets of transmitting and receiving transducers. Each set transmits and receives ultrasonic signals obliquely to the ground. One set is arranged to detect the forward or astern velocity of the ship, the other set to detect the port or starboard velocity of ship.

Figure 7 shows the principle of a typical ultrasonic Doppler speed-over-ground meter. This device indicates fore-aft velocity and port-starboard velocity.

$$Vfa = \tfrac{1}{2}(Vf - Va)$$

$$Vps = \tfrac{1}{2}(Vp - Vs)$$

where Vfa = velocity fore-aft
Vps = velocity calculated with fore beam by the principle of Doppler frequency shift

$$Vps = \frac{\Delta f}{2f} : \frac{S}{\sin \theta}$$

f = original frequency of sound
Δf = Doppler frequency shift
θ = incident angle of beam
S = velocity of sound in water

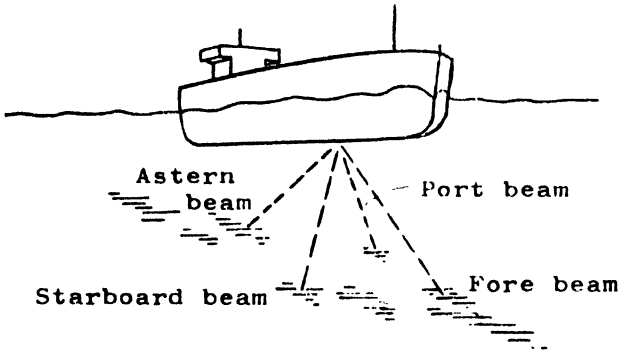

Fig 7. Beam arrangement of typical Doppler velocity meter

Vf, Va, Vp, Vs have a component velocity of up and down which is eliminated because it is the same for each. Velocity components caused by rolling and pitching are hot eliminated. This can be done by stabilizing the beam.

Fish counters have to discriminate single fish within the effective sound beam (fig 8). Single targets are discriminated by serial group echo information. Correct distinction requires electronic data processing (EDP). Targets which are closer together in distance than one half the pulse length show a great variety of echo configurations and patterns of micro-structure. Analysis or synthesis of such echoes in order to detect the number of targets is very difficult. Such patterns can be simulated

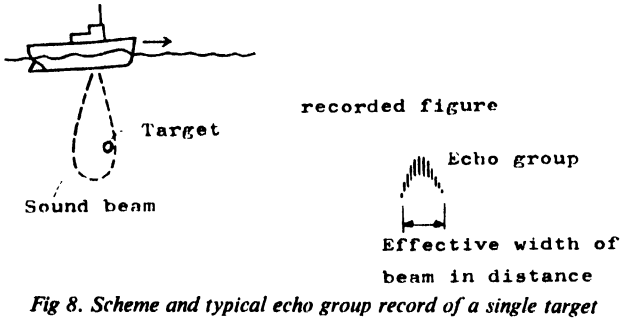

Fig 8. Scheme and typical echo group record of a single target

with EDP, but discrimination by EDP treatment on board a ship has difficulties because the EDP system has to have many recognition patterns stored. Beam stabilization is a prerequisit and simple mechanical stabilization is satisfactory for vertical fish detecting and counting.

NOISE INTERFERENCE WITH SONAR

There are many ambient noises which reduce sonar activity. Environmental noise of the sea, ship's noise while running and water noise caused by friction at the

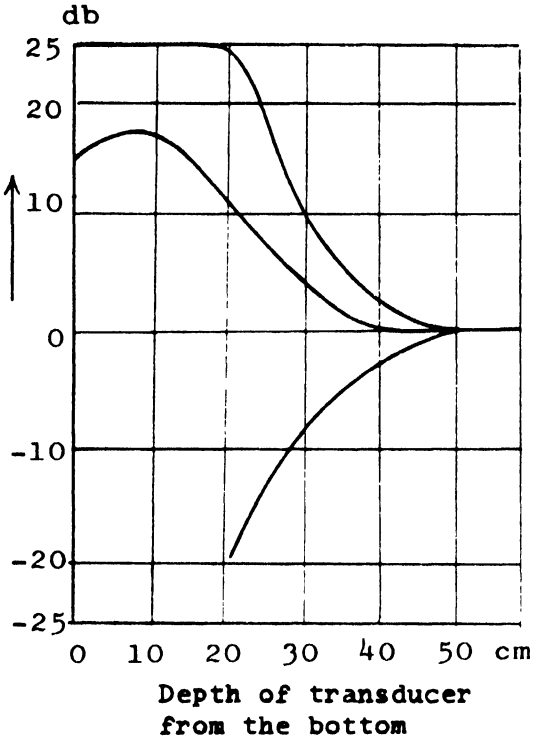

Fig 9. Typical example for attenuation, noise and access of sound with relation to transducer distance from the hull

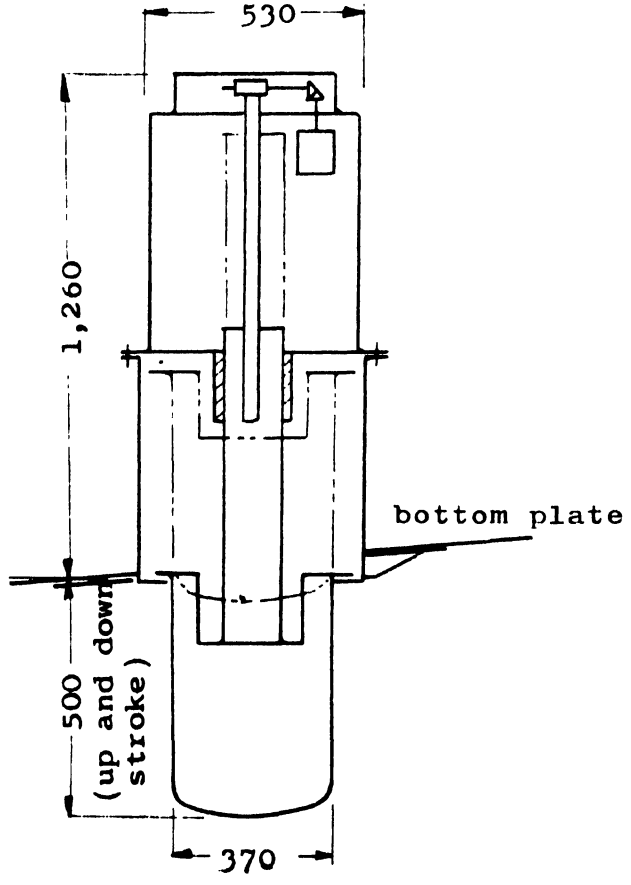

Fig 10. Installation of retractable gear

transducer or acoustic window of the sonar dome are examples which can influence the S/N (sound/noise) level. Noise caused by mechanical vibration of main and auxiliary engines and by the propeller is not easy to reduce. Noise and absorption of acoustic signals caused by the boundary layer (air bubbles) around the ship depends partly on the sea state. The most effective action against the latter is to place the transducer out of the boundary layer (fig 9).

The interference by boundary layers is not uniform at any position of the ship's bottom but extended installation of the transducer is effective at any position and for any type of ship. Fixed installation of transducers extending more than 30 cm from the ship's bottom creates problems in dry docking. Retractable installations are therefore preferable (figs 10 and 11).

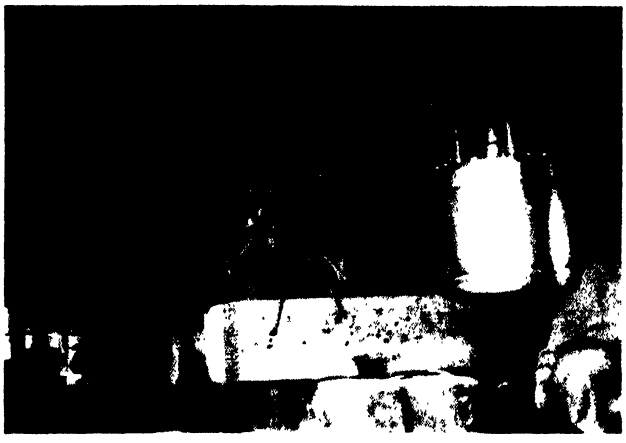

Fig 11. Outside view of dome

Fish Detection Echo Sounding System with Electronically Stabilized Narrow Beam and Bottom Locked Display

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Un système de détection des poissons par écho-sondage comportant un faisceau étroit stabilise electroniquement et un enregistrement a fond fixe

Au cours des années, l'expérience a montré que l'équipement conventionnel d'écho-sondage souffre d'un certain nombre d'inconvénients quand on l'utilise pour la détection des poissons, et en particulier des espèces démersales. On a remédié à l'un de ces inconvénients, à savoir le déplacement des échos détectés par suite du mouvement du navire, au moyen de l'enregistrement avec fond fixe. D'autre part, l'erreur faite dans la mesure de la distance qui sépare le poisson du fond de la mer nécessite une amélioration de la définition directionnelle de l'écho-sondeur. En raison du roulis du bateau de pêche, une stabilisation verticale du faisceau étroit est par ailleurs nécessaire si l'on veut détecter avec certitude des poissons isolés. Pour obtenir cette stabilisation, les méthodes diverses, à la fois mécaniques et électriques, qui étaient employées dans les premiers temps ont été remplacées en général par des equipements complexes, de fabrication et d'installation coûteuses. Le système décrit a été conçu pour être suffisamment sensible pour détecter par une profondeur de 550 m (300 fm) une petite morue se trouvant à moins de 7,3 m (24 ft) du fond, tout en étant comparativement bon marché à fabriquer et à installer. La performance requise est obtenue en stabilisant seulement le faisceau d'émission contre le roulis du navire. l'oscillateur de réception conservant une largeur de faisceau habituelle dans le sens transversal. Dans le plan longitudinal, les angles d'ouverture des oscillateurs d'émission et de réception sont respectivement de 8 et 4,5°. Leur ouverture est suffisante pour permettre de recevoir les échos sans perte, malgré le tangage du bateau. L'oscillateur d'émission est constitué par un ensemble de 18 éléments a magnétostriction, d'une fréquence de 45 kHz, montés suivant le plan transversal du bateau. Les faces de ces éléments sont coplanaires et les faisceaux ont des angles d'ouverture de 3,5° transversalement et 8° longitudinalement. Il y a un affaiblissement du champ de directivité dans les deux directions. Chaque élément de l'oscillateur est alimenté par un émetteur de 350 watts. Le faisceau émis (3,5°) est stabilisé à moins de $\pm\frac{1}{2}°$ pour un roulis de $\pm 15°$ par des décalages de temps successifs entre les impulsions des éléments, sous le contrôle d'un gyroscope de référence vertical. Les performances de l'équipement et les résultats de son utilisation au cours de voyages de pêche commerciale sont précisés.

Detección de peces con sistema de sondeo acustico de haz estrecho estabilizado electronicamente y representación del fondo en linea recta

A lo largo de los años, la experiencia ha demostrado que el equipo tradicional de sondeo acústico presenta desventajas cuando se emplea para la detección de peces, especialmente si se trata de especies demersales. Une de estas desventajas—el movimiento de los ecos representados visualmente, a causa del movimiento del barco—se ha superado mediante la representacion del fondo en linea recta. Otra de ellas—el error que se produce al calcular la distancia del pez sobre el fondo del mar exige un haz estrecho, de impulsos acusticos para aumentar la capacidad de resolución de la ecosonda. Además, el balanceo del pesquero hace necesaria una estabilización vertical del haz estrecho para poder detectar con certeza los peces individualmente. En el pasado se han empleado varios métodos, mecánicos y eléctricos, para estabilizar el haz acústico, pero en general todos ellos requieren equipos complejos, de fabricación e instalación costosa. El sistema descrito es suficientemente sensible para localizar un pequeño bacalao a una profundidad de 300 brazas y a una distancia de 24 pies del fondo del mar y su construcción e instalación son relativamente baratas. Para obtener el rendimiento necesario basta estabilizar el haz transmitido con respecto al balanceo del barco, mientras el transductor receptor tiene un haz de anchura tradicional (25°) en el plano transversal del buque. En el plano longitudinal, los ángulos del haz de los transduccores transmisor y receptor son, respectivamente, 2° y 4,5°. Ambos son suficientemente amplios para permitir la recepción de los ecos sin pérdidas, a pesar del cabaceo de la embarcación. El transductor transmisor consta de una serie de 18 elementos magnetostrictivos, sintonizados a 45 kHz y montados en el plano transversal. Las superficies de esos elementos son coplanares y los ángulos del haz son de 3,5° en la transversal del buque y de 8° la longitudinal. Se registra un sombreado en el esquema de directividad en ambas direcciones. Cada elemento del transductor actúa impulsado por un transmisor de 350 w. Con balanceos del buque del orden de 15°, el haz transmitido (3,5°) se estabiliza dentro de un margen de $\pm\frac{1}{2}°$, espaciando sucesivamente las emisiones de impulsos acúst cos de los elementos, generadas bajo el control de un giroscopio vertical de referencia. Se dan datos sobre el rendimiento del equipo y se describen los resultados obtenidos con su empleo en expediciones de pesca comercial.

ACOUSTIC echo sounding equipment has been used for detecting fish for many years. Sensitivity and resolution of apparatus commercially available for fishing vessels has noticeably improved, so that it is now possible to obtain an echo from a single 12 in (30 cm) cod at a depth of 250 fm (450 m). Nevertheless, these equipments have limitations and the equipment performance falls short of what is required.

In commonly used echo sounding equipment, the fish and sea-bed echoes are shown on a recorder chart or cathode ray tube. Because of ship motion, the sea-bed echoes usually appear on the chart as an undulating, rough-edged mark, fish echoes are uncorrelated, and the corresponding signals on the cathode-ray tube move in position from transmission to transmission. Examination of these signals may be made much less tiring by use of a bottom-locked display (Ellis *et al*, 1963; Haslett *et al*, 1970). Estimates and measurements of, for instance, the relative position of a fish echo to the sea-bed echo, may now be made with confidence through a new development.

The problem outlined

The situation occurring generally when a vessel rolls is shown in fig 1. The ambiguity in measurement of fish above the sea-bed is due to the spreading of the acoustic energy within a finite cone whose effective vertex angle is about 10° to 20°. The echo sounder is capable only of displaying the range of targets within this cone and not their bearing with respect to the axis of the acoustic beam. Consequently, the fish at positions three and four, although at different bearings, will appear to be at the same range. They will also appear to be just above the sea-bed, which has only a marginally greater range than both fish. Moreover, if the solid line 2 indicates the height of the trawl headline above the sea-bed, it would not be unreasonable to conclude from the displayed signals that both the fish at positions three and four are catchable. In shallow water, the ambiguity is not usually serious, but in 200 fm (360 m) with an athwartships transducer beam angle of 13°, it can be as much as 7 ft (2.1 m). If the trawl headline is normally 8 ft (2.4 m) above the sea-bed, then many fish shown on the display as apparently beneath the headline, are in fact above it. A further disadvantage occurs because of the greater magnitude of the sea-bed echo than that of a fish target. The ratio of the sizes can be of the order of 1,000 so that an echo at position five can be easily swamped by the sea-bed echoes occurring at shorter ranges. This fish, although at a height above the sea-bed which makes it a probable catch, is not indicated on the equipment display at all.

The height ambiguity may be reduced by using a narrower beam angle athwartships. To be effective, however, the beam width must be reduced to such an extent that the rolling of the trawler will cause the occasional loss of vertical soundings. Even now, the ambiguity will only be reduced for targets immediately beneath the ship. For off-vertical targets, it is not reduced to a sufficient extent. It becomes necessary for an effective performance to stabilize the narrow beam to point always vertically downwards. If then, for instance, a beam angle of 3.5° is used, the height ambiguity in 200 fm (360 m) may be reduced to 1 ft (0.3 m) and the situation is as shown in fig 2 where the fish above the headline is not recorded. Considering the echo sounder as a sampling device, a more accurate measurement of the distribution of catchable fish may be made with a stabilized narrow-beam system.

To stabilize an echo sounder beam to point continually, within small angular limits in a vertical direction is not technically difficult. It can be done by mechanical stabilization of the whole transducer assembly, or electrically, usually by the use of phase-shifting networks

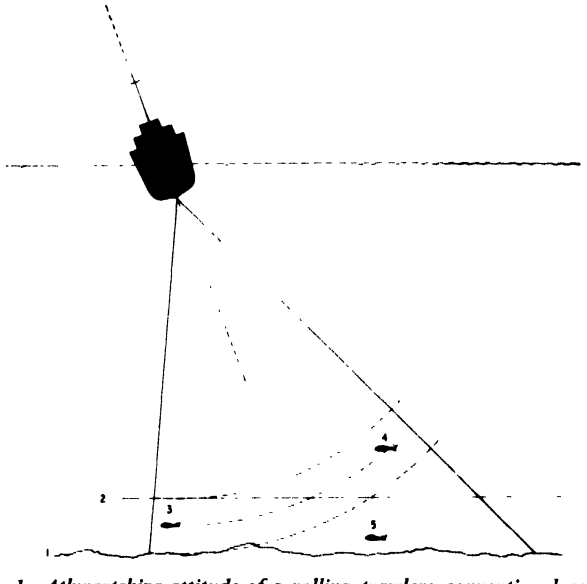

Fig 1. Athwartships attitude of a rolling trawler: conventional echo sounding equipment (after Ellis et al., *1968)*
1 = Sea bed; 2 = Height of trawl headline; 3 = Fish under headline; 4 = Fish above headline; 5 = Fish whose echo will be obscured by the sea bed echo.

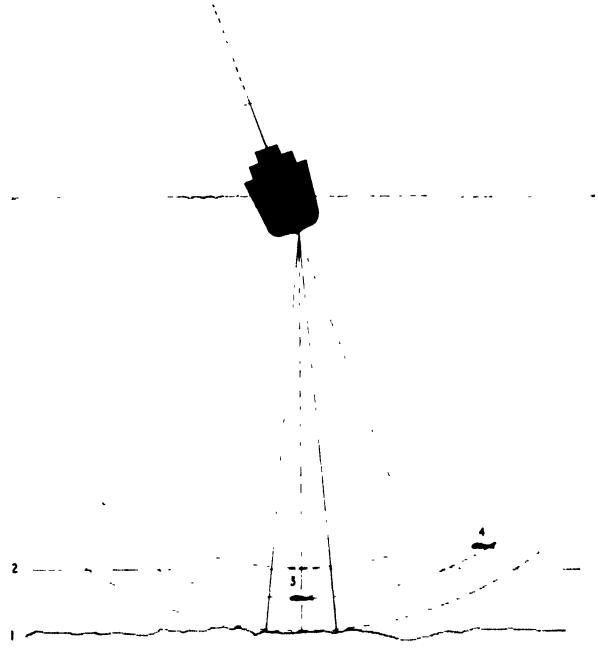

Fig 2. Athwartships attitude of rolling trawler: stabilized narrow-beam system (after Ellis et al., *1968)*
1 = Sea bed; 2 = Height of trawl headline; 3 = Fish under headline; 4 = Fish above headline

associated with the elements into which the transducer must be sub-divided. Such systems are usually complex and expensive in themselves, besides requiring extensive ship work to allow installation of the equipment. Certain simplifications in manufacture can allow the cost and ship work to be reduced and yet produce adequate performance. For instance, stabilization of the acoustic beam against rolling and not pitching of the ship need only be provided. Any fish within the region scanned will eventually, on all practical counts, pass directly under the ship as it steams forward, so its height may be measured directly from the recorder chart or CRT trace. It is also adequate to stabilize the transducer beam either on transmission or on reception, and not in both modes. The transducer used for the unstabilized mode is then designed to have an athwartships beam angle wide enough so that its sensitivity in the vertical direction is sufficiently great at all angles of roll.

NEW SYSTEMS REVISED

These various considerations led to the decision to develop a system with a vertically stabilized acoustic beam for use in commercial trawlers. The scheme received substantial support from the White Fish Authority of Great Britain for whom three sets have been made.

It was decided the transmitter beam would be stabilized only against ship's roll. For reception, a transducer with a large face area to provide good capture area and a wide beam angle in the athwartships plane would be provided.

To stabilize the transmitted beam, the acoustic projector is divided into 18 elements. Each element is provided with its own electronic transmitter which can generate about 350 W of electrical power in a pulse which is no greater than 0.5 ms in length (Halliday and Hopkin, 1963). Each transmitter is triggered by a pulse and the time at which the triggering occurs is determined by the attitude of the ship with respect to a vertical reference gyroscope, so that the time interval between the transmission of acoustic pulses by adjacent elements is such that the signals add in phase to produce a vertically directed beam. The way in which the stabilized beam is actually produced is described in more detail later.

The range resolution of the equipment is determined by the length of the acoustic pulse which can be produced—the shorter the pulse, the better the resolution. At any given carrier frequency, the length of the shortest acoustic pulse which can be transmitted is determined by the mechanical characteristics of the transducer. Also, the higher the carrier frequency the shorter is the pulse which may be obtained. Because at high frequencies the attenuation of sound in sea water becomes excessive, a compromise choice of carrier frequency allows the required range to be obtained and yet gives a useful range resolution. Weighing various factors resulted initially in the choice of 30 kHz as the carrier frequency and two pieces of equipment were built and tried extensively at sea. The results suggested that a shorter pulse would be an advantage. Consequently, for later equipments a frequency of 45 kHz was used. This frequency, together with a new transducer design, gives a pulse length of about 0.25 ms.

THE EQUIPMENT

Of the two kinds of equipment which have been built, that operating at 45 kHz is described, consisting essentially of:

- (a) Transmitter rack
- (b) Vertical reference gyroscope } Between decks
- (c) Motor alternator
- (d) Bridge unit
- (e) Display equipment } On the bridge
- (f) Transmitting transducer
- (g) Receiving transducer } On the ship's hull

The transmitter rack shown in fig 3 contains five units which, from top to bottom, are:

(i) A double-beam oscilloscope for waveform monitoring and for use in setting-up the equipment.
(ii) A unit which contains the circuits controlling the sequencing of the triggering of the 18 transmitters, one of which is associated with each transducer element. On the front panel of this unit are mounted the 36 potentiometers for the various tuning adjustments of the transmitter triggering circuits.
(iii) A unit containing the 18 transmitters.
(iv) A power supply unit.
(v) A phase-sensitive detector unit which accepts the electrical signal from the gyroscope. The nature of this signal is a measure of the ship's attitude with respect to the vertical and it is converted by this unit into a form suitable for controlling the transmitter triggering circuits.

Vertical reference gyroscope

This is a low-speed gyro and produces high momentum with low stored energy. It incorporates a squirrel-cage induction motor in which the squirrel-cage assembly, forming part of the gyro wheel, rotates about the stationary three-phase field assembly. The speed of rotation is approximately 2800 rev/min. The motor is fed from the steered narrow-beam equipment supply of 240 V, 50 Hz by means of a step-down transformer and phase-splitting capacitors mounted in the gyro case.

The gyro is mounted in a gimbal that allows 2° of rotational freedom and is made pendulous by a weight attached to the bottom casing. If allowed freedom, the gyro will have a conical precession period of about 4 min. An electro-magnetic erection system reduces the time taken for the gyro to assume a vertical position and corrects for wander due to friction and horizontal acceleration. The system is controlled by a mercury change-over switch and the gyro maintains vertical position to within $\pm 0.5°$.

Port and starboard roll indication is obtained from a rotary pick-off, mechanically linked to gyro movement. Twenty volts, 400 Hz is fed to one winding of the pick-off and an output is obtained from the other winding

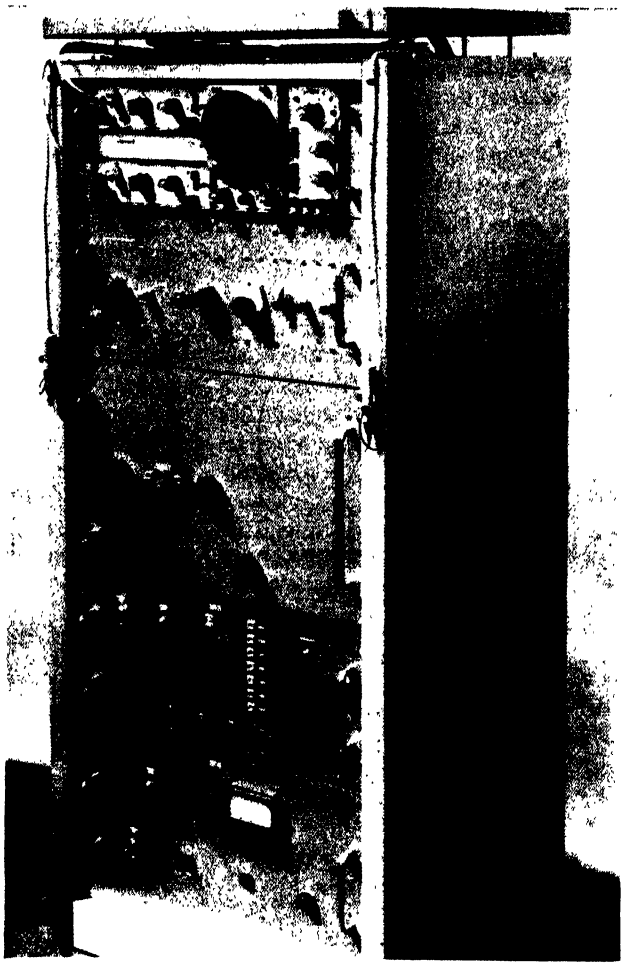

Fig 3. Stabilized narrow-beam system: transmitter rack

proportional to the ship's roll, within the limits of ±15°. Diagram (fig 4) shows essential features of the circuit.

A positive-going pulse from a trigger circuit in the standard echo sounder recorder is passed to the monostable multivibrator stage in each of the two ramp-generator circuits. Each ramp-generator is associated with the driver circuits for half of the 18 transducer elements. The resultant ramp pulses are fed into the driver stages where they are compared with the bias voltage on the emitter of the input transistor. In turn, the magnitude and sign of the bias voltage is derived from the gyro pick-off output signal. The output from the blocking oscillator stage in each driver unit is passed to the pulsed, wave-train generator stage in each transmitter.

At zero steer, with the gyro at the vertical (0°), the blocking oscillator pulses from the 18 driver stages must start together to preserve the correct time relation between output pulses generated by each transmitter. To achieve this a small amount of bias is applied to the emitter of the input transistor in each driver pick-off stage. This bias level is adjusted by pre-set controls mounted on the driver chassis front panel.

With the ship rolling to port or starboard, a signal voltage derived from a rotary pick-off on the gyro, is amplified and passed to a phase-sensitive detector stage. The phase change of the signal voltage with respect to its reference voltage is detected by the phase-sensitive stage, the resultant voltage being rectified and smoothed. The smoothed output from the phase-sensitive detector stage is passed to a steer-angle meter, a roll sensing relay stage and the off-set bias control.

The roll sensing relay stage is normally off and is only switched on by positive going signals (starboard roll) from the phase-sensitive detector stage. With the

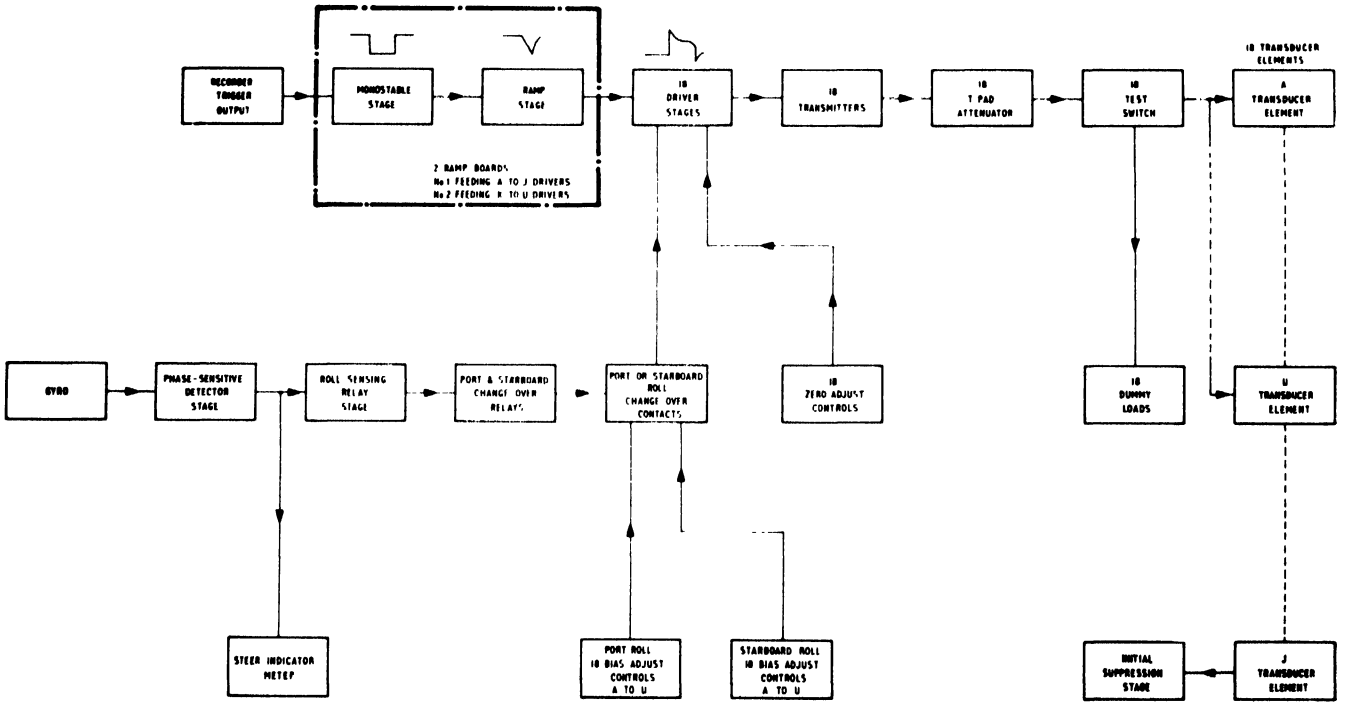

Fig 4. Stabilized narrow-beam system: block diagram of steering circuits

stage switched on, a relay incorporated in the collector circuit of a transistor is energized and its contact closes, connecting a 6 V DC supply to the three change-over relays on the driver chassis.

The change-over relays, energized by the 6 V supply from the sensing stage, connect the signal voltage from the phase-sensitive detector stage to the emitter of the first transistor in the driver stages via the "starboard bias adjust" potentiometers. These controls are set individually to ensure that each transmitter operates in turn at time intervals of 5.7 micro-sec for a 15° roll. With the ship rolling to starboard, the port transducer "A" transmits first, followed by "B" and so on to transducer "U". With this time interval between the transmissions from individual elements, the acoustic pulses all have the same phase in the vertical direction so that this direction is the acoustic axis of the beam. When the ship rolls to port the sensing stage is switched off, opening the sensing relay contact which de-energises the change-over relays. These contacts change over and connect the signal voltage to the emitter of the first transistor in the driver stage via the "port bias adjust" potentiometers. With the ship rolling to port, the arrangement is such that the starboard transducer "U" operates first followed by "T" and so up to transducer "A".

Each transmitter consists of three stages: (1) a pulsed wave-train generator, (2) a driver stage, and (3) an output stage.

In the pulsed wave-train generator, a thyristor is used to discharge a capacitance through an inductance to produce a damped wave-train which is shaped and amplified by the driver and output stages. With this arrangement it is easy to synchronize the firing of the individual thyristors so that all transmitters are under the sole control of the gyro information. The driver and output stages are conventional transformer-coupled transistor-stages providing a pulsed output power of 350 W into a 30 ohm load. The transmitter output stages are connected to "T" pad attenuators so that the output across the transducer face is tapered according to a Gaussion law. The output may be switched so that an untapered array is obtained if required. An additional switch is also provided for switching the individual transmitter outputs into dummy loads for test purposes.

The bridge unit

This unit contains the mains supply switch, the meter which shows the angle through which the acoustic beam is steered and, if a Humber equipment is also fitted in the ship, the controls for switching from one system to the other.

After reception, the signals are amplified and passed to the display equipment. This consists essentially of four units: (a) standard echo sounder recorder, (b) signal selection and storage unit, (c) cathode-ray tube scale expander, (d) recorder scale expander—all mounted on the bridge.

Standard display—A standard echo sounder is used. In the past, this has been of the rotating-arm type but in future it will be a straight-line recorder of improved performance. The instrument (fig 5) can use wet or dry paper of 8½ in (0.2 m) width so that 14 in (0.35 cm) of paper is in view at any time. The pen is driven through

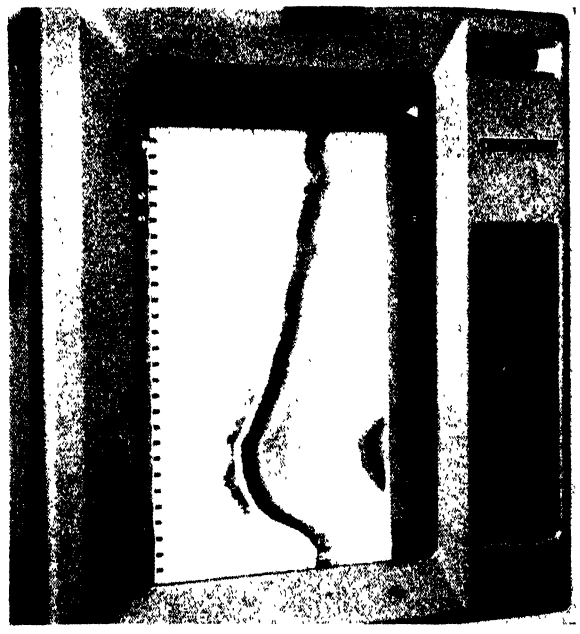

Fig 5. Standard echo sounder recorder (after Haslett et al., *1970)*

an "electronic gear box" so that its speed is accurately controlled. The receiving amplifier can give the familiar "White Line".

Sea-bed locked displays—For this the cathode-ray tube and recording scale-expanders are used in conjunction with the signal selection and storage unit. Effect of ship motion on echoes over the recording surface is removed by stabilizing the display with respect to the sea-bed echo—thus giving a steady picture of this region. In particular, the regions 2½ fm (4.5 m) or 5 fm (9 m) above the sea-bed may be examined. This degree of range expansion, together with the enhanced trace-to-trace correlation of fish echoes obtained by using the sea-bed lock, enables the fish echo to be more readily distinguished from that due to the sea bed than is possible with a standard display.

The signal selection and storage unit is used for selecting the signals for triggering the scale-expander display circuits, also for storing the signals which are to be displayed. In this way, the sea-bed echo and near bottom fish echoes corresponding to one acoustic transmission, can be used to trigger the CRT time-base and can be continuously replayed until the sequence of echoes from the following transmission is due. This gives a very bright CRT picture which allows easy examination (see fig 6). The recording scale-expander, using the same signals, provides a permanent record of sea-bed and fish echoes. Its use eliminates continuous watch of CRT display (see fig 7).

The transducers

Both tranducers are of magnetostrictive type, have a resonant frequency of 45 kHz and a mechanical Q of 10. Consequently the shortest pulse consistent with the bandwidth which may be transmitted is about 0.25 ms in length. In each case magnetic biasing of the transducer material is obtained by ferrite permanent magnets inserted into slots in the back face of the stack of nickel laminations of which the transducers are made.

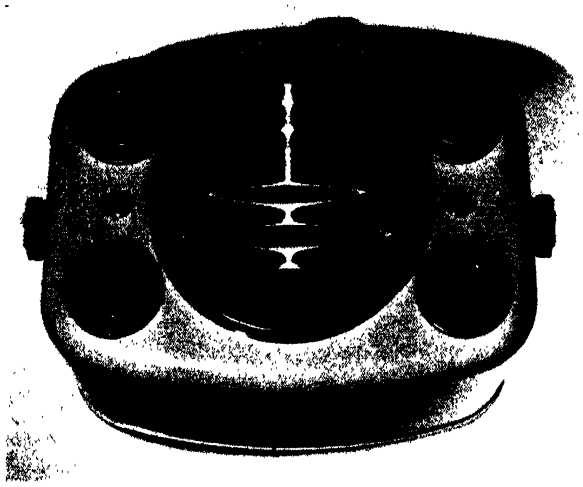

Fig 6. Stabilized narrow-beam system: CRT display unit (after Hopkin and Haslett, 1964)

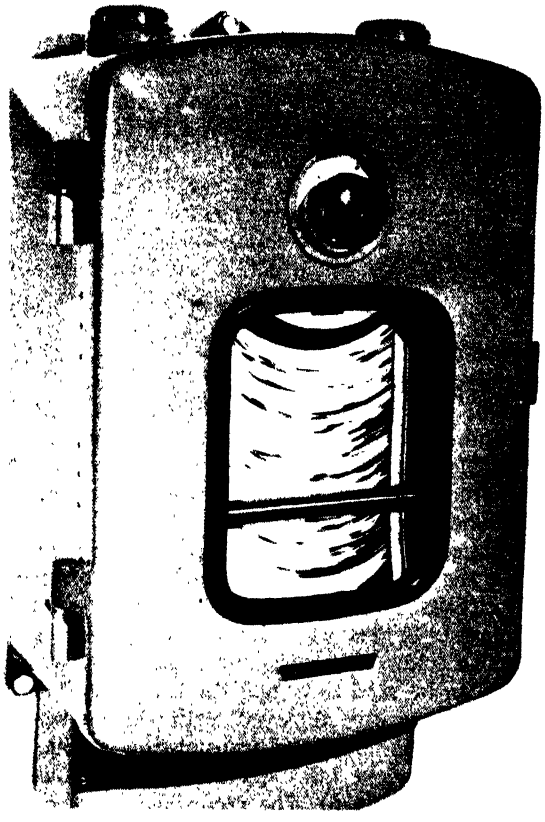

Fig 7. Stabilized narrow-beam system recording scale expander

The transmitting transducer (fig 8) consists of 18 individual elements. Each element has a radiating face which is 2 in (5 cm) wide, i.e. about 1 wavelength wide at 45 kHz, and is 10 in (25 cm) long. The element is divided along its length into nine sections and the amount of active material is progressively reduced in each section from the centre section outwards. This dilution of active material varies the acoustic output from the centre of the stack towards the ends without reducing overall efficiency and produces in the plane of the length of the stack a directivity pattern with a reduced number of

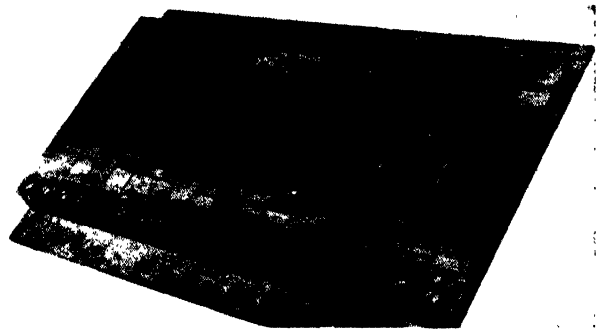

Fig 8. Stabilized narrow-beam transmitting transducer (45 kHz)

side-lobes. Tapering of the directivity pattern in the other plane is obtained by reducing the electrical drive to the elements from the centre element outwards. This transducer is mounted on the ship with its long dimension athwartships and is so constructed that if any element should become faulty, it may be taken out without removing the whole transducer from the ship. Two wires from each of 18 elements go up into the vessel through a 36-hole hull-gland. Inside the ship, the element conductors go into a junction box where each element is individually tuned. From this box, an 18-core coaxial cable runs to the electronic equipment.

The receiving transducer has a radiating face of approximate dimensions 2.4 in (6 cm) × 14.4 in (36 cm) ($2\lambda \times 12\lambda$ at 45 kHz). It is made of four stacks of laminations each about 2.4 in (6 cm) high and is fitted with its long dimension fore and aft so that it has a wide beam of about 25° athwartships. The beam angle fore-and-aft is about 4°. The conductors from the transducer go into the ship through a 2-hole hull-gland, then to a junction box containing the tuning condenser, and so to the receiving equipment.

PERFORMANCE OF EQUIPMENT

Attention has been concentrated on the performance of the transmitting equipment, its acoustic source level and the properties of the steered beam. The receiving and display systems are those used in the Kelvin Hughes Humber equipment.

The nature of the transmitted beam was studied on an acoustic range. Figure 9A gives the directivity pattern in the fore-and-aft, unsteered, direction—the direction in which there is dilution of the active material in the transducer stack. A beam angle between 3 dB points of 9° is obtained, and the side-lobe level is about −15 dB.

Figure 9 B, C, and D show the directivity patterns for zero steer and for steering angles of 5° and 15°. The beam angle is about 3° for the unsteered beam and increases to about 3.6° when the steered angle has its maximum value of 15°. Except at this steering angle, the side-lobe is not greater than −23 dB. At the maximum steering angle, the side-lobe level rises to −17 dB and a second lobe—the so-called "grating" lobe—begins to appear at an angle of 60° from the main lobe. This occurs because of the relationship between the size of the elements of the array and the angle of steering.

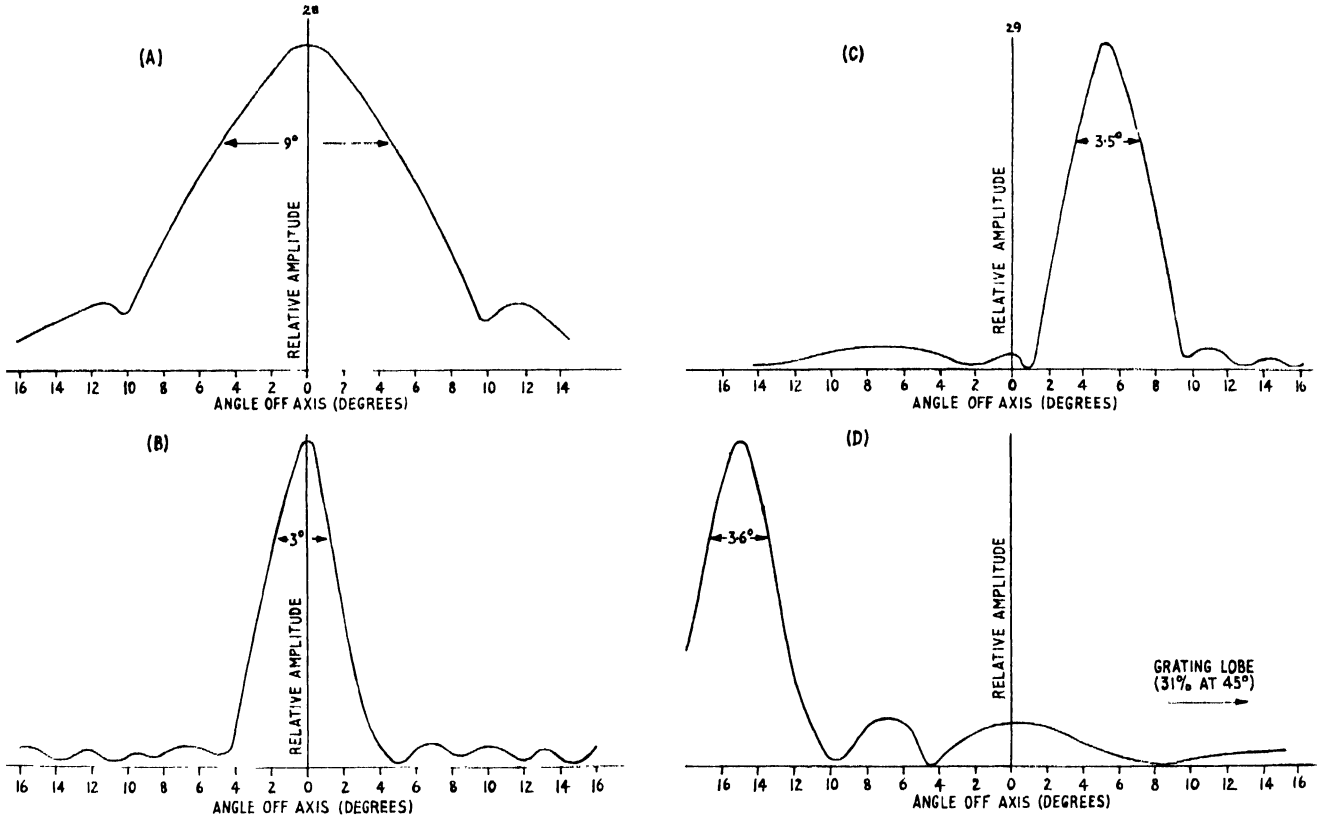

Fig 9. 45 kHz SNB transducer
(A) fore and aft direction; (B) athwartships direction, unsteered; (C) athwartships direction steered 5° starboard; (D) athwartships direction steered 15° port

The source level of the equipment is measured to be 130 dB vs 1 μ bar at 1 yd, a level which is equivalent to that of the Kelvin Hughes Humber equipment.

Performance at sea

Both the 30 kHz and 45 kHz versions of the equipment have been operated at sea on commercial distant-water and stern trawlers but the lower frequency equipment has had much more extensive use.

The experience (Drever and Ellis, 1969) gained during these fishing voyages has shown that the system has its benefits, although in some ways the results obtained have not been as good as expected. It has been found that the displayed information needs careful examination—a skipper used to the echo charts obtained from a conventional echo sounder finds that it must be interpreted differently. For instance, because in the stabilized narrow-beam system the beam is narrower than that of the conventional echo sounder, a smaller volume of water is examined by any one transmitted pulse. Particularly, therefore, the bottom-locked display will show echoes from a smaller volume of water adjacent to the sea-bed, so that, for a given distribution of fish, fewer fish echoes will be obtained. For a given catch-rate, the number of fish recorded is smaller.

Figure 10 shows recording scale-expander charts from the stabilized narrow beam equipment and Humber equipment, which were obtained simultaneously, although necessarily with equipments using different carrier frequencies. The chart from the narrow-beam

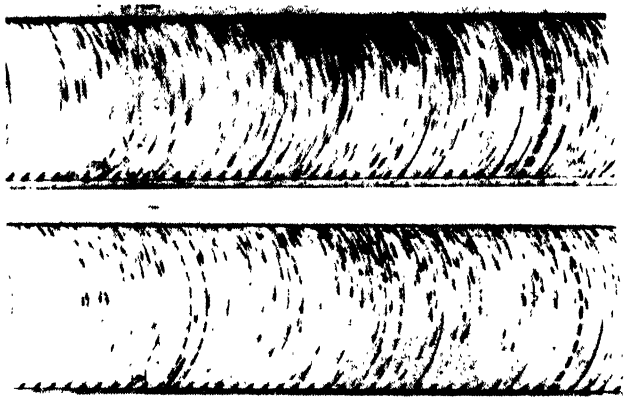

Fig 10. Two recording scale-expander charts obtained simultaneously (after Ellis et al., *1968)*
Upper: stabilized narrow-beam equipment at 45 kHz. Lower: Humber fish detection equipment at 30 kHz.

system shows noticeably fewer echoes due to the use of the narrow beam than that from the more conventional equipment. Such records are generally obtained when the fish are off the bottom but in the limiting case where all the fish are down on the bottom the recordings are essentially the same for both types of equipment. That this is so may be seen by reference to fig 1. If all fish are between the solid line 2 and sea-bed echo 1, and if the solid line 2 progressively approaches the sea-bed, the angle subtended at the ship by the area containing fish which gives echoes distinguishable from that of the sea-

bed becomes smaller and smaller, whatever the transducer beam angle. When using the stabilized narrow-beam system, it is suggested (Drever and Ellis, 1969) that the use of the calibration tow when fishing starts is essential to obtain a correct fish echo/catch ratio and to establish confidence in the performance of the apparatus.

One benefit of the system is that the true height of fish above the sea-bed is given. The bottom-locked CRT display is particularly useful in this respect, as the fish echoes may be displayed very clearly. Figures 11 and 12 (photographs of CRT display) taken whilst trawling, show this well. To find fish immediately beneath the vessel when fishing along a sloping edge is also more likely and there is also a greater probability of finding fish amongst hills on the sea-bed. To improve the performance in this respect, the original equipment (operating at 30 kHz) was redesigned for a carrier frequency of 45 kHz to give a shorter pulse. Comparison of results from the two equipments suggests that, in fact, no noticeable improvement in this aspect has been obtained.

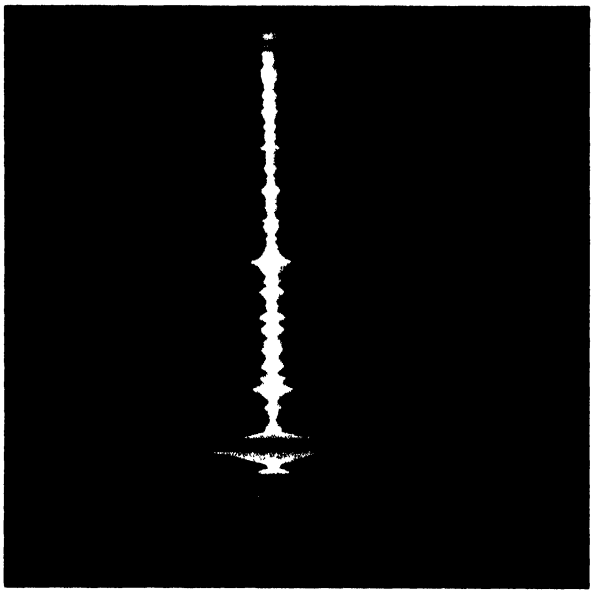

Fig 11. Stabilized narrow-beam system CRT display. A fish echo above the sea bed echo (after Ellis et al., *1968)*

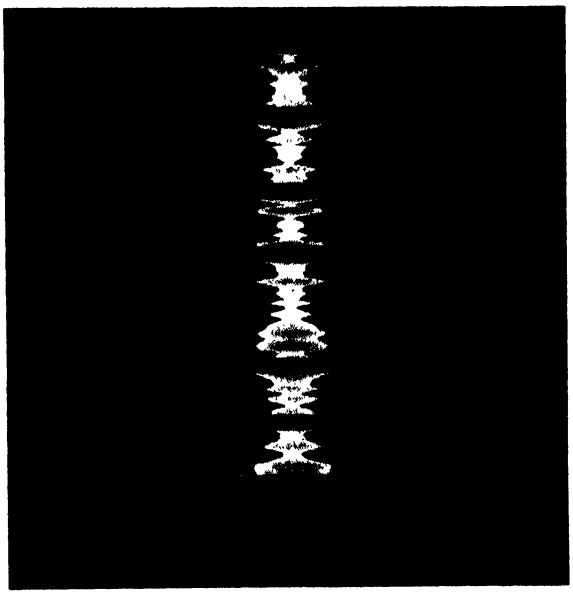

Fig 12. Stabilized narrow-beam system CRT display. Several fish echoes above the sea bed echo (after Ellis et al., *1968)*

An advantage is that echoes from small organisms do not produce such a high background signal-level against which the important fish echoes must be distinguished (Drever and Ellis, 1969). This reduction in background is again a result of using a narrower effective transducer-beam. A smaller volume of water is examined than with the conventional equipment and it contains fewer small targets giving less unwanted background.

The stabilized-beam equipment has been found particularly useful when fish such as cod are interspersed with dense formations of sand eels. When an equipment with the conventional wide-beam is used where fish are above the sea-bed, then echoes from several fish all at the same range, but not necessarily at the same bearing, can be received from several successive transmissions (see fig 1). The typical hyperbolically shaped marks, one from each fish, tend to overlap and produce a record on the recording scale-expander which is very similar to that from a school of sand eels. With the use of a narrow acoustic beam, because the volume of water examined is so much smaller, fewer of the commercial fish are present so that fewer echoes are obtained from these fish and there is consequently less chance of echoes overlapping - it is easier to distinguish individual fish. The echoes from the sand eels, however, still give their typical dense recording, due to close formations. The cathode-ray tube display also helps in this case to identify the cod and sand eels because of the different echoes. The stabilized narrow-beam equipment certainly gives an advantage in this case.

POSSIBLE FUTURE USES OF SYSTEM

Modern trawlers are tending to fish deeper and deeper, so that fishing at 500 fm now occurs. No current commercial fish-detection equipment is capable of recording echoes from the smaller commercially exploited fish at these depths, but there will be a need for such an apparatus if this deep fishing becomes common. The detection of fish targets in these conditions is limited by water noise so that improvements in the detection properties of the receiving apparatus will probably be made by sophisticated signal processing, although the transmission of greater acoustic powers at perhaps lower frequencies may be used to improve detection performance. However, if the carrier frequency is lowered, then so, in general, is the range resolution. For a detection resolution equivalent to that of existing equipments, a frequency of about 30 kHz still needs to be used. If larger acoustic powers are to be transmitted, then larger transducers than those now used in conventional equipment are needed. (Even now, the more powerful equipments are producing a peak acoustic pressure which is near the the value producing cavitation in sea water.) These larger transducers thus need to be stabilized against ship motion. Furthermore, if a conventional transmitter is used to drive such a transducer at a high level, then

larger and more expensive transmitting valves and other components will be required.

It therefore becomes apparent that the system which has been described has great advantages for driving narrow-beam transducers at high power-levels. Already a large transducer driven nowhere near its maximum output level is used, and apart, at the moment, from the vertical reference gyro, the electronic equipment is built from inexpensive conventional components.

Acknowledgements

Acknowledgements are due to Kelvin Hughes, a Division of Smiths Industries Limited, for permission to publish this paper, and to the White Fish Authority for use of some information. The authors also thank Dr. R. W. G. Haslett for help in preparing the paper, and Mr. G. H. Ellis whose great experience has been indispensable.

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A Fish Counter for Use in Commercial Fishing

P. J. Hearn

Un compteur de poissons utilisable en pêche commerciale

On met au point actuellement un système de comptage des échos de poissons qui peut être relié à l'oscillateur de réception de n'importe quel sondeur détecteur afin de prévoir la prise et le rendement de pêche des chalutiers de fond. Le prototype actuel consiste en:

(*a*) Une section de groupage des données qui recueille les échos de poissons traités par un gain variable en fonction du temps (TVG) sur une distance choisie à partir du fond, et qui comporte aussi un circuit digital pour la profondeur;

(*b*) Une section de traitement des données qui réalise les calculs de réglage et de correction à partir des échos de poissons;

(*c*) Des contrôles et des indicateurs qui affichent d'une manière continue la prévision de la prise, le taux de capture, la profondeur (par un nombre) et enregistrent la profondeur et le taux de capture. Les contrôles comprennent l'incorporation des pêches réellement effectuées.

Au cours d'essais en mer prolongés, on a obtenu une précision globale de moins de ± 50 pour cent sur les prévisions de capture, avec environ 35 pour cent de ces prévisions à moins de ± 20 pour cent près. Jusqu'ici, ceci est déjà considérablement mieux que les prévisions moyennes du patron de pêche. On espère que le système qui doit encore être amélioré apportera une aide marquante aux patrons de chalutiers en ce qui concerne la prise de décision tactique.

Contador de peces para empleo en la pesca comercial

Se está preparando un sistema de recuento acústico de peces que puede conectarse al transductor receptor de cualquier ecosonda para la localización de peces y permite predecir la captura y el coeficiente de captura de los arrastreros que pescan en el fondo. El prototipo actualmente existente consta de:

(*a*) Sección de recogida de datos, que recoge los ecos de los peces de una zona seleccionada del fondo del mar teniendo en cuenta la ganancia de amplificación de la señal seguin el recorrido y tiene un cicuito numérico para la profundidad;

(*b*) Sección de elaboración de datos, que realiza cálculos para corregir y reajustar los ecos de los peces;

(*c*) Representacion y control de los datos, mostrando la predicción continua de la captura, el coeficiente de captura y la profundidad (numerica), y registración de la profundidad y el coeficiente de captura. Los aparatos de control registran también las captura reales.

Ex experimentos extensivos realizados en el mar se obtuvo una exactitud media en las predicciones de las capturas del orden de ±50 por ciento y en un 35 por ciento de las predicciones se logró una exactitud de ± 20 por ciento. Se trata de un resultado notablemente mejor que el consequido hasta ahora con las predicciones normales de los patrones. Se espera que, mejorado ulteriormente, el sistema será muy útil para los patrones de los arrastreros a la hora de tomar decisiones de carácter práctico.

OVER the past few years there has been continual improvement in the technical performance of vertical echo sounders used to detect demersal fish. The engineer or scientist can readily appreciate these improvements. But can the trawler captain? On average, the answer to the question is no.

One approach to assisting the captain is to consider the main instrument, to see how it is used by a top class captain and how it can be altered or extended to simplify its use. This approach led to the development of a fish counter which would predict the catch and catch rate, albeit crudely by scientific standards.

EARLY INVESTIGATIONS

So the White Fish Authority of Britain placed a study contract with Kelvin Hughes to carry out a detailed review of existing fish counting methods coupled with an appreciation of the theoretical problems involved and to contain proposals for equipment to be developed (Hopkin, 1967).

The first experiment was to count the fish indicated on the triggered pen charts of the Kelvin Hughes Humber Gear Fish Detection Equipment. This display is of the bottom 4 fm and shows fish marks, in various height bands from the sea bed, which were counted and related to the known catch for that particular tow period. From this work over several hundred tows it was not possible to establish a single calibration constant or correlation law which would relate the count of fish marks to the catch.

The next approach was to apply some proposals recommended in Hopkin's report using simple electronic circuits. A unit was designed which, using the drum storage system of the Humber Gear, would gate out the returns from each sounder transmission and, suitably shaped, pass these signals on to a standard commercial counter. The time span of the sample taken was equivalent to either 2 ft, 4 ft, 8 ft or 24 ft bands above the sea bed. The Humber Gear was calibrated and, during the trials, the gain of the equipment was set according to depth so that the counter would operate from a 10 in (25 cm) fish. The counter was started when the trawl gear was all square on the sea bed and stopped when the command for hauling was given. The count per tow was processed by the inverse square of the depth to compensate for two effects: (a) the echo duration or the number of "pings" from a fish increase with depth and (b) the area of the vertical cross section scanned by the sounder is proportional to depth whereas the area sampled by the trawl is constant. Therefore, greater weighting must be given to the echo count of fish in shallow water.

Log sheets detailing the ping counts, catch and depth were obtained for several hundred tows over several voyages of four ships. Again, from this data it was impossible to establish a single value or correlation law relating the count of fish "pings" with the actual catch. However, during these trials it was realized that the skilled captain uses the relationship between fish displays and the catch on previous tows to estimate the present catch. The data of fish ping count and catch already gathered was therefore used in a prediction formula based on exponential smoothing. The relationship used was:

$$R_F(t+1) = R_A\alpha + (1-\alpha)\,R_{Ft}$$

where $R_F(t+1)$ = Forecast ratio for the next tow

R_A = Actual ratio obtained from the tow just completed

R_{Ft} = Forecast ratio used for the tow just completed

α = Smoothing constant

It can be seen that, if α is made equal to 1, the prediction $R_F(t+1)$ is made from data obtained from the previous tow. The calculations were made on an Elliott 903 computer using values of α of 0.1 to 1. From this work emerged the first evidence of the possibility to predict a catch and it was shown that the best correlation between fish count and catch was when the count was made in the 4 ft band. In broad terms a catch could be estimated to within $\pm$ 50 per cent for about 60 per cent of the time.

This level of accuracy is not surprising. There are many unquantified reasons for the variability in the relationship. Some are biological, for example, the temperature of the sea, whether the fish are feeding and their reproduction cycle all affect their reaction speed and the amount of light affects their behaviour in relation to the trawl. Other reasons are acoustic, for example, the variable coupling between the transducer and the water, the inability of the sounder to discriminate fish hard down on the sea bed and the height ambiguity problem where the sounder with the conventional wide beam does not give an accurate indication of the true height of fish off the bottom. Fish on the edges of the beam can be at the same range as those directly below the vessel and yet be above the trawl headline.

A method of overcoming this latter problem is to narrow the effective beam width. However, from a very limited sample it was found that using the narrow beam extension to the Humber Gear only increased the number of predictions within the $\pm$ 50 per cent band by a few per cent.

The value of the crude adaptive system is shown in fig 1 where two prediction methods are used; one being the adaptive and the other a constant multiplier using the mean obtained by averaging over the whole voyage. For a short period until a disturbance at about Tow No. 265, the predictions by the two methods are of similar accuracy. After the disturbance, the adaptive method recovers but the predictions from the constant multiplier method continue to fall off.

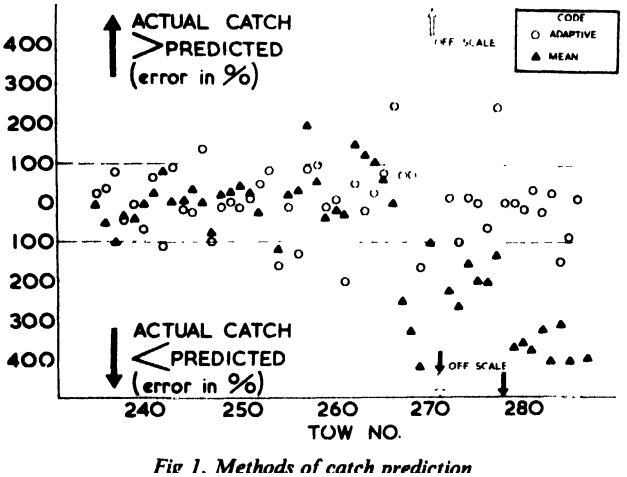

Fig 1. Methods of catch prediction

THE FISH COUNTER

From early investigations, a specification was derived for a counter which could be the prototype for a commercial instrument. The design permits the unit to be attached to any echo sounder receiving transducer but is independent of the receiver circuits and displays of that sounder. For some applications, it may replace those circuits and displays.

The equipment can be considered in three parts: (1) a data gathering section, (2) a data processing section and (3) displays and controls. The unit (fig 2) is covered by patent No. PA.51276/68.

Displays and controls

It was decided the following displays would be most useful:

(a) continuous prediction of catch
(b) catch rate
(c) depth, in digital form, and
(d) depth and catch rate, as an analogue, displayed together on a chart recorder.

Displays (a) and (b) allow the captain to make best use of his fishing time and to correctly load his factory deck. Display (c) was introduced for ease of contour

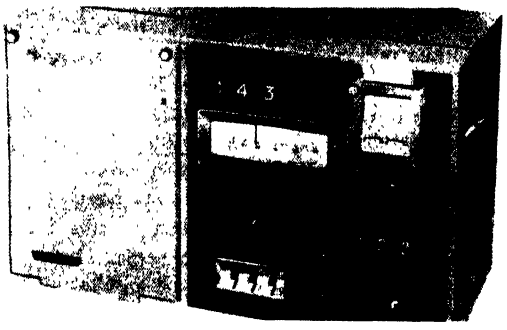

Fig 2. The prototype fish counter

fishing and displays (d) are an aid to the captain when deciding tactics of the next tow, e.g. whether to repeat in reverse the same tow or to manoeuvre to fish out a large school of fish and, if the latter, where to lay the course.

Controls necessary are:

(a) START and a STOP button
(b) thumb wheels for setting up the captain's estimate of present catch when landed on deck
(c) ENTER CATCH button, and
(d) CLEAR COUNT button.

The latter button is guarded to prevent accidental operation and is used to cancel the present count stored in the data processing section when the catch is obviously in error due, say, to a torn cod-end. In these circumstances, the conversion figure used for that tow is used again for the next, rather than the normal procedure of up-dating the multiplier at the end of each tow.

Data gathering section

Signals for this section are taken from the transducer of the associated echo sounder and passed through an amplifier with time varied gain (TVG). The amplified outputs of signals which have been gated to be close to the sea bed are then clocked into a shift register which is stopped on the reception of the sea bed pulse. The stop control is determined by an amplitude and slope circuit which is designed to allow through a pulse should there be a fish on the bottom.

The shift register has 11 stages which, at a clocking rate of 6.3 kHz, gives an equivalent delay of 1.75 ms. This in turn, means a store of the pulses received from the bottom 4 ft on each transmission. Following the reception of a sea bed pulse, the content of the shift register is emptied into the data processing section.

The data gathering section also contains the digital depth circuits. Basically, the system is to scale the digitised time between the transmission pulse and the sea bed return. Time gating is introduced to discriminate against close-in reverberations. Similar equipment has been described by Cooke (1966).

Data processing section

This section is essentially a small special purpose digital computer. The required computation could be made by either an analogue or a digital machine but the latter was chosen to fit into the expected pattern of development in the larger fishing vessels, in which digital computers are likely to be introduced in the next few years. Already the White Fish Authority have contracted for the development and manufacture of an extensive control and alarm scanning system for a stern/freezer trawler's engine room and refrigeration plant. This system employs a general purpose digital computer which will be expected to carry out a number of other duties including fish counting.

The calculations required from the data processing section are simple. The count of pulses from the shift register is divided, on each transmission, by the square of the depth (D^2), the result is multiplied by the prediction ratio, R_{Ft}, and, suitably scaled, the output is used to drive the displays. The count from the shift register is, of course, between 0 and 3 for the average echo sounder and the value divided by D^2 presents calculation difficulties. The value is, therefore, multiplied by a large constant so that the required accuracy can be obtained without handling values below 1 in the following stages.

The other calculation required is to solve the equation $R_F(t+1) = R_A\alpha + (1 \quad \alpha)R_{Ft}$ between tows.

The calculation is carried out after the captain has set up his estimate of the catch obtained on the previous tow and immediately following his pressing the ENTER CATCH button. The inserted catch estimate is first compared with the sorted value of the depth corrected cumulative count of fish echoes to obtain R_A and then this value is used in the solution of the above formula. Should the catch returned on deck be non-representative due to the obvious loss of fish as a result of trawl gear damage, then the stored corrected fish count is cleared by operating the CLEAR COUNT button and the stored R_{Ft} is used again for the next tow.

TRIALS ON THE FISH COUNTER

During the last quarter of 1969, the prototype counter was installed onto the side trawler *Westella* and this year has also been used on the stern/freezer trawler *St. Jason*; in both cases in association with the 30 kHz Humber Gear fish detection equipment.

The results from these trials tend to confirm the original findings and, for a whole trip, the predictions are within $\perp$ 50 per cent of the actual catch for about two thirds of the time. The results from the *St. Jason* also showed that 35 per cent of these predictions were within $\pm$ 20 per cent. These are the findings for complete voyages and the accuracy will depend on the number of significant changes in the environmental conditions, e.g. changes of ground, behaviour of fish.

TABLE 1. EXTRACT FROM *St. Jason* FISH COUNTER LOG SHEET

Tow No.	All Square	Knock out	Depth fm	baskets forecast	actual baskets
17.1.70					
22	0115	0345	150	60	60
23	0430	0630	160	73	70
24	0723	0755	169	15	12*
25	0845	1125	165	51	5*
26	2105	2210	150	20	20
27	2325	0155	150	69	60
18.1.70					
28	0320	0610	150	59	70
29	0745	1025	150	71	85
30	1100	1310	150	41	70
31	1430	1730	150	55	73
32	1915	2215	155	40	85
33	2244	0135	145	104	70
19.1.70					
34	0217	0330	145	86	70
35	0620	0822	150	75	80
36	1000	1210	150	53	70
37	1445	1700	150	71	50
38	1740	2015	175–220	46	70
39	2145	0145	210	82	25
20.1.70					
40	0235	0428	200–225	24	40
41	0525	0755	210	33	40
42	0900	1025	200–230	25	30
43	1118	1400	180–250	44	45
44	1527	1852	170–205	46	120
45	2035	2220	180–200	139	140
46	2305	0210	115–225	151	40†
21.1.70					
47	0355	0654	190–210	144	50†
48	0750	1008	145–160	51	25†
49	1208	1450	200	52	60
50	1538	1830	200	65	100
51	1910	2125	195	103	100

* Warp pulled out hauled Cod-end out.
† Cod-end torn. Cod-end out.

Over shorter periods, of course, the accuracy can be greater as indicated in Table 1, where, for the same grounds, i.e. 53° N 52° 30′ W, the summary of results from the *St. Jason* for day and night fishing over a period of five days (Table 1) is:

13 out of 30 predictions within ± 20 per cent of actual catch

23 out of 30 predictions within ± 50 per cent of actual catch

Of the remaining seven predictions, four were in error due to low catch being returned resulting from cod-end damage. Statistically, the results for complete voyages approximate to a Gaussian distribution with a standard deviation of about 9 per cent. These results are much better than the average man can achieve over a full voyage and will be of value to top class captains. Indeed, the top class captain with whom we have conducted the trials is already using the instrument in decision making.

FURTHER WORK

The *St. Jason's* results were obtained with the instrument selected to operate with $\alpha = 1$, i.e. predicting from the results of the previous tow only. It appears, however, that there is no significant improvement using any other value of α. This has been shown by shore based calculations using a recorded value of the depth corrected fish count of each tow.

If this result is confirmed over many voyages, it will be possible to simplify the electronic circuits by removing the calculation.

A further circuit simplification would be to remove the continuous correction for depth and apply a mean depth value for the tow. Therefore, in addition to logging the depth corrected count, the uncorrected count is also recorded for each tow. These values have been processed on shore using the mean of the recorded depth for that tow in the calculation. The results obtained, however, have been less accurate than those from the method of continuous depth correction.

It is intended these trials should continue during 1970 and be extended by introducng a second prototype counter. This counter is likely to be altered in some of its circuitry so that the corrected and uncorrected counts mentioned can be automatically logged, thus removing the need for engineering staff to accompany the unit on all voyages. The dislays will also be changed; the particular analogue meter display of catch rate has proved unacceptable and is likely to be replaced by a digital meter and the chart recorder will probably be made larger and separate from the main unit for easier use.

Later in the year and as a result of full commercial experience, the unit design will be reconsidered for production. There is already indication that the calculation for various α values is not required and it is expected that further modifications will be made before the equipment is on the market in 1971.

Acknowledgements

This paper is presented by permission of the White Fish Authority who initiated the work. The contractor responsible for the design and manufacture of the prototype counter was Kelvin Hughes, a division of Smiths Industries Ltd.

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Development of Echo Counting Systems for Estimating Fish Stocks in Japan

K. Shibata, N. Nishimura, T. Aoyama, I. Yamanaka

Developpement des systemes de comptage par echo pour l'estimation des stocks de poisson au Japon

On trouve au Japon quatre sortes de systèmes de comptage de poissons pour l'estimation des stocks au moyen d'appareils acoustiques. Il s'agit des compteurs directs d'échos de poissons sous la forme d'individus et de bancs, du système d'analyse de la répartition des traces de poissons (Ishii et Tanaka, 1969) et du système d'intégration optique des échos. Un aperçu succinct de ces systèmes acoustiques est fourni. Les résultats d'expériences fondamentales préliminaires en mer permettent de penser que les deux types de compteurs d'échos et l'intégrateur optique pourront être utilisés pour l'estimation de l'abondance du poisson sur les lieux de pêche. On espère qu'un résultat positif pourra être obtenu par la réalisation d'expériences consécutives au cours des deux prochaines années.

Creacion de sistemas de recuento acustico para estimar las poblaciones de peces en el Japón

En el Japón existen cuatro clases de sistemas para determinar las poblaciones de peces por medio de aparatos acústicos. Son éstos los contadores directos por eco de los distintos peces, cardúmenes, sistema de análisis de huellas de peces (Ishii y Tanaka, 1969) y sistema integrador óptico de ecogramas. Se presente un breve esquema de estos sistemas acústicos. Basándose en los resultados de los experimentos fundamentales de carácter prelipinar hechos en el mar, se cree que para estimar la abundancia de peces en los caladeros se deben emplear los dos tipos de contadores por eco e integrador óptico. Se espera tener éxito en los experimentos consecutivos que se realizarán en los próximos años.

IN 1968, a governmental cooperative research project was established for the development of acoustic methods of estimating fish stocks. This project included, FM (frequency modulated) sonar, a biotelemetering system and an echo counting system for estimating fish stocks. In addition, research was started on a pattern analysis system independent of this project.

In 1969 there were three types of acoustic systems for estimating fish stocks; (1) echo counters for individual fish, (2) echo counters for fish schools, and (3) optical integrators for analysis of echograms of fish school. Since May 1969 preliminary fundamental tests were carried out in a tank at the Tokai University and several field experiments using artificial targets were made in order to investigate the accuracy of counting and to clarify problems involved in the application of these devices for estimating fish stocks. The fundamental experiments on the echo counter for individual fish were made on the initiative of the Far Sea Laboratory and Tokai University (Nishimura and Yamanaka, 1970) and those on the echo counter for fish schools and optical integration of echograms were carried out at the Seikai Regional Fisheries Research Laboratory and Nagasaki University.

The outline of those fish counters and some results of fundamental experiments are here described. Since no observations associated with fishing operations have been made no information is available on the interrelation between catch per unit effort and fish abundance measured by echo counter.

INDIVIDUAL FISH COUNTER

The block diagram of the echo counter for individual fish is shown in fig 1. It is composed of an echo sounder with TVG (time varied gain), a binary circuit which resets the average number of echo pulses per fish, a signal generator for the counting range in depth, a computing circuit, a digital indicator and a printer.

The number of echoes is corrected in the computing circuit on the basis of three factors, i.e. ship's speed, thickness of fish school and volume of water sampled by the sound beam. The final data are shown in terms of numbers of fish per unit volume of water sampled. The

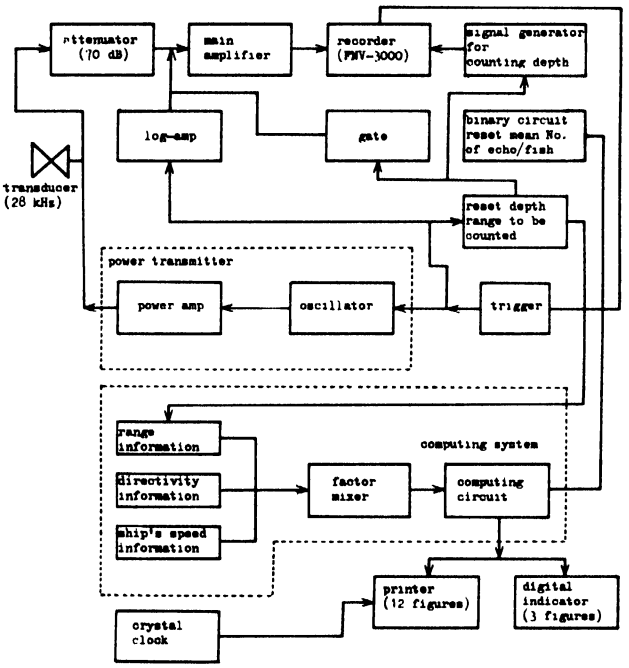

Fig 1. Block diagram of echo counter for individual fish

specifications of the principal parts of the counter are:

Echo sounder: commercial type (FURUNO FNV-3000) with moist paper recorder; acoustic frequency: 28 kHz; pulse length: 2 ms; pulse repetition rate: 90/min; electric output: 2kW; beam width: 9.7° at half power.

Maximum depth of fish to be counted: 300 m for medium size tunas, target strength (Ts) = 22 dB.

Counting increments: 10, 20 and 50 m, shiftable from 10 to 400 m depth.

Digital indicator: 3 digits, number of fish per unit volume of sampled water in cubic meter (10^4, 10^5, 10^6, 10^7, and 10^8)

Printer: 12 digits typewritten; 4 digits for time, 3 for fish density, 1 for index of sampled volume of water and 4 spare.

Ship's speed correction: 1 knot steps from 2 to 10 knots.

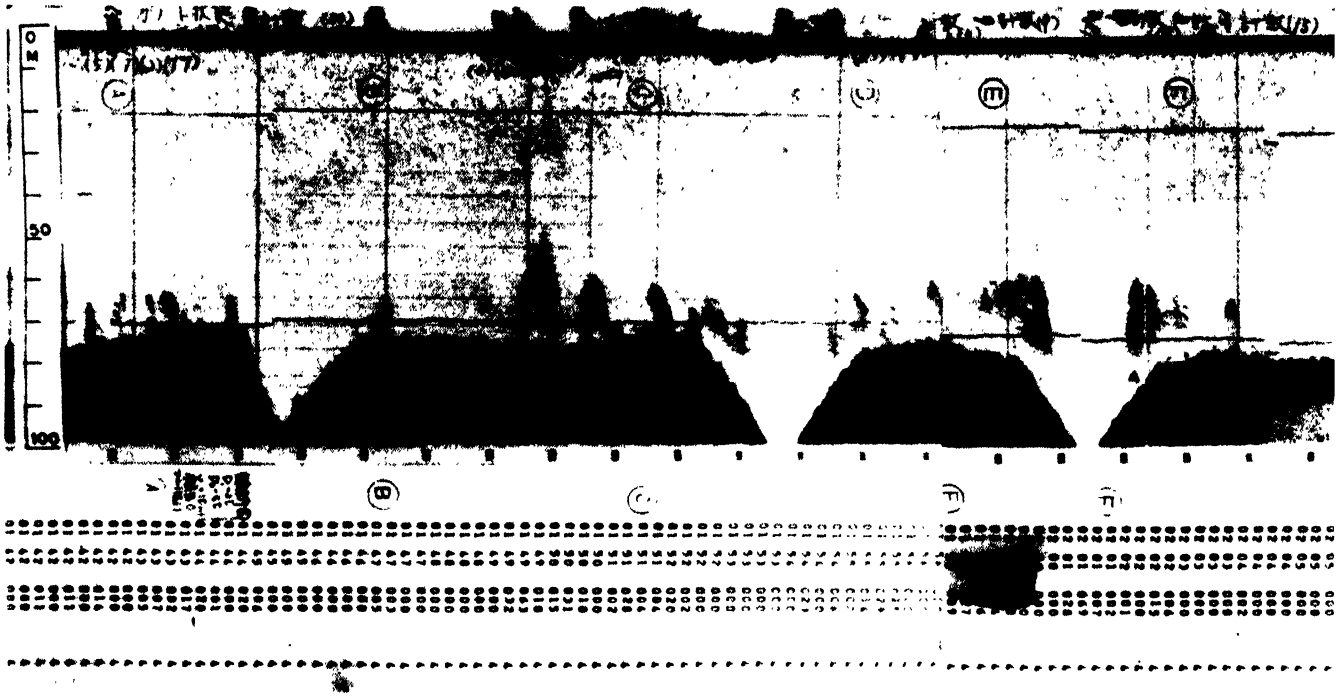

Fig 2. Quantitative fish detection in Surugo Bay in September 1969 on board the "Hokuto" of Tokai University. The lower part is a data sheet of the individual fish counter, and marks A to F correspond to the respective marks in the upper echo chart. For example, mark A, 01 43 $005_4 4_3$ is interpreted as 01 h 43 min 5 fish per 10 m

Results of fundamental experiments

Several series of field experiments for checking accuracy of the counter were made in Suruga Bay on board the *Minamijuji* (20 GT) of Tokai University.

The research boat with the fish counter installed was anchored in a depth of 25 m of water, and the number of echoes per unit time interval was counted for the sea bed and also for a given rectangular vinyl board (58 × 109 × 1 cm in size). The readings of the counter were given as 92.8 per unit time interval in an average of nine observations for the rectangular board at a depth of 14 m, and 98.2 in an average of 11 observations for the sea bed. In both cases the readings varied slightly with a deviation of several per cent.

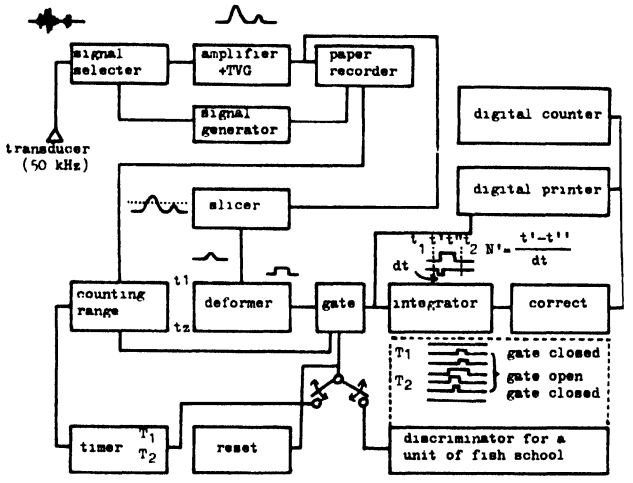

Fig 3. Block diagram of echo counter for fish schools
$N = \int^{t} \int^{T} t\, dt\, dT$
where, dt = 1 m: dT = one transmission: t = pulse length of echo from the fish school

Other experiments were made using one or two glass balls which were placed underwater at depths of 35 and 50 m. The boat ran with a constant speed of 4 kn over these targets and the readings of the fish counter were averaged 8.7 in four observations of one target and 18.5 for two targets. In this case it can be said that the number of echoes was almost proportional to the number of targets. Similar experiments were successfully carried out for small tuna at sea.

Quantitative fish detection was carried out in Suruga Bay on board the *Hokuto* of Tokai University in the summer of 1969, and the total cruise distance was about 120 miles. Fig 2 shows an echo chart and data sheet obtained in this survey.

The experiments on fishing grounds will be continued until good results can be obtained.

ECHO COUNTER FOR FISH SCHOOLS

The echo counter for fish schools is an electronic system to count echoes for estimating the magnitude of fish schools, e.g. anchovy, sardine, mackerel, etc. In other words the counter is a sort of planimeter for echograms of fish schools.

The block diagram of the school counter is shown in fig 3 and a photograph of the counter system on the deck of a purse seiner (18 GT) is shown in fig 4. The system consists of four parts, an echo sounder, an integrating circuit, a digital indicator and a printer.

The counter indicates "1" upon receipt of one echo from a target of 1 m thickness during one transmission. If a series of echoes from a fish schools of 10 m thickness are received during 100 transmissions, the counter indicates "1000". The duration of counting is controlled in three

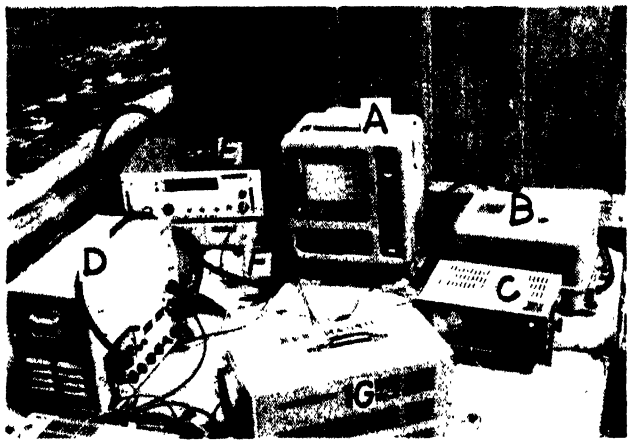

Fig 4. Echo counter for fish schools on a purse seiner (18 GT). A = echo sounder, B = pulse transmitter, C = audio part, D = counting and integrating part, E = digital indicator of 5 digits, F = data printer, G — oscilloscope

ways, i.e. by manual operation, by a clock switch and by an automatic switch which discriminates fish schools as units. The latter enables the printing of the total integration of the readings of the echo counter for fish schools separately and the counter is reset for each school.

The specifications of the principal parts of the counter are:

Echo sounder: commercial type with moist paper recorder (SANKEN, SL-16); acoustic frequency: 50 kHz; pulse length: 0.5 and 2 ms; electric output: 2 kW; pulse repetition rate: 225 to 56/min; beam width angle at half power: 25° × 10° in 3 dB down.

The depth range increments of fish schools to be counted is 10 to 200 m.

Digital indicators: 5 digits for index of dimensional area of echogram of fish school.

Data printer: 5 digits for fish school index, 5 for measurement of conditions, i.e. ship's speed, beam width, time interval counting or testing.

Ship's speed correction increments: 2.5, 5 and 10 kn.

Results of experiments

Three series of fundamental experiments were carried out on board fishing boats and the research vessel *Kakusui* of Nagasaki University in Ohmura Bay, Chijiwa Bay and neighbouring waters of Nagasaki Port from September to November, 1969. The stability of counting for several kinds of targets (breakwater wall of Tokitsu Port, trapnet and immersed glass balls of 20 cm dia) was checked in Ohomura Bay on 8 and 9 September 1969 and good results were obtained in each series of experiments. The reading for the breakwater wall is proportional to the echo level (Table 1).

Quantitative fish detection on the Chijiwa Bay fishing grounds for anchovies, *Engraulis japonica*, was carried out on board a purse seiner (18 GT) from 10 to 12 September 1969. An echo chart and data sheet on 10 September are shown in fig 5. In this data sheet, five digits of the upper part show measurement conditions, one each indicating counting or testing, counting time interval, pulse repetition rate, beam width, and ship's speed. The digits in the lower part give dimensional specifications of echo sounding, e.g. counting by fish school units, 225 pulses/min, beam width of 25° at half power, underway speed of 10 kn. The fish school index, "O" does not mean absence of fish but has a relative value of less than 1.

The direct counting readings of this counter are proportional to the dimensional area of the fish school traces measured by a planimeter (fig 6).

The last experiment survey to study the fish attracting effect of underwater lamps was carried out in the neighbouring waters of Nagasaki Port on board the *Kakusui* of Nagasaki University on 6 October 1969. A small fish school of anchovies was detected at about one hour after sunset and then underwater lamps (500 W × 3) were immersed above the school at a depth of 2 m while drifting. Quantitative observations were made using the echo counter for 100 min at a range of 5 to 25 m and the readings were printed at intervals of one min. The result is shown in fig 7. The attracting effect and short migrating

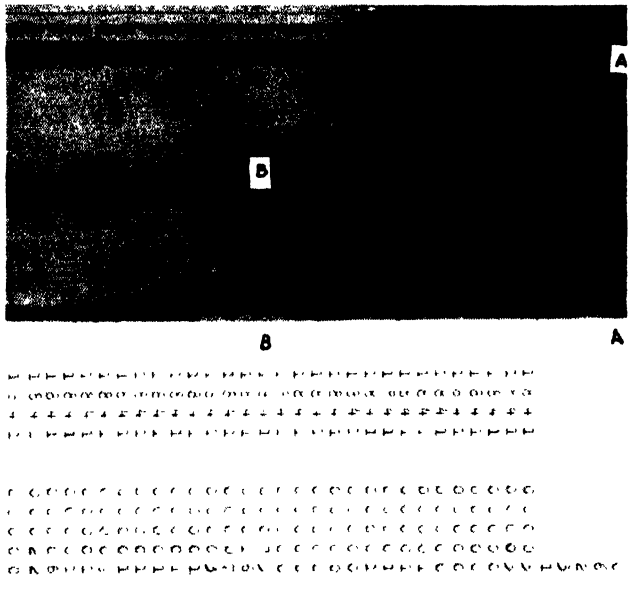

Fig 5. Quantitative fish detection in Chijiwa Bay on 10th September 1969. Top: echo chart of 50 kHz echo-sounder in depth range of 50 m. Bottom: data sheet printed by fish school counter

TABLE 1. CHANGE OF READINGS OF FISH SCHOOL COUNTER AGAINST THE LEVEL OF ECHO FROM A BREAKWATER WALL.

Relative echo level re noise in dB	2	7	12	17	22	27	32	37	42
Readings									
Average	12.5	55.0	149.5	269.3	386.7	471.3	557.7	776.3	985.5
Maximum	15	60	152	280	391	489	565	782	1025
Minimum	10	50	146	259	379	460	548	772	970
Number of observation	2	2	4	3	3	4	3	4	3

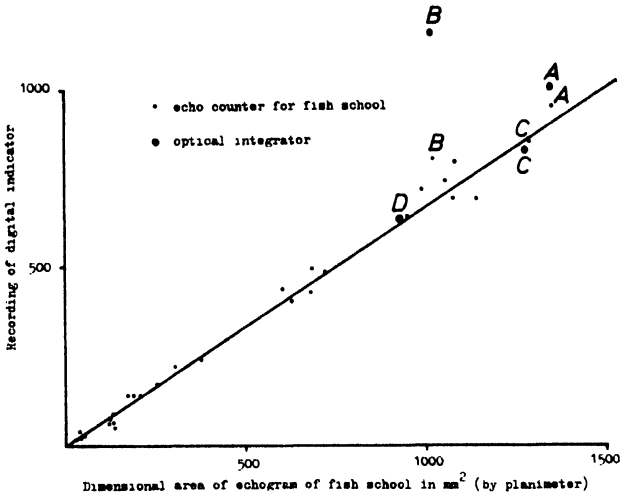

Fig 6. Relation between dimensional area of echogram of a fish school by planimeter, the readings of direct echo counter for a fish school and of the optical integrator. A, B, C and D are fish schools detected in Tachibana Bay as shown in Table 1, small spots are the readings of the direct echo counter on board the purse seiner and the larger spots are readings of the optical integrator in the laboratory

period of the fish around the lamps is now being calculated by computer. The result could possibly be applied to the study on the schooling behaviour of fish.

OPTICAL INTEGRATOR FOR FISH TRACES

The colour density and dimensional size of fish school traces vary with their size and scattering characteristics. The optical integrator for echograms integrates roughly the dimensional area as well as the colour density of traces by means of a colorimetric determination technique. Thus the readings of the optical integrator should be considered as an indication of the amount of fish and it is advantageous that the analysis of echo chart recordings of acoustic surveys with this system can be made in a laboratory as well as at sea.

The block diagram of this system is shown in fig 8. The system is divided into two parts, optical and integrating. The optical part is composed of a paper feeding system, light source, standard photo-cell for the non-coloured part of the echogram and reading photo-cell for fish school traces. The reading photo-cell can be

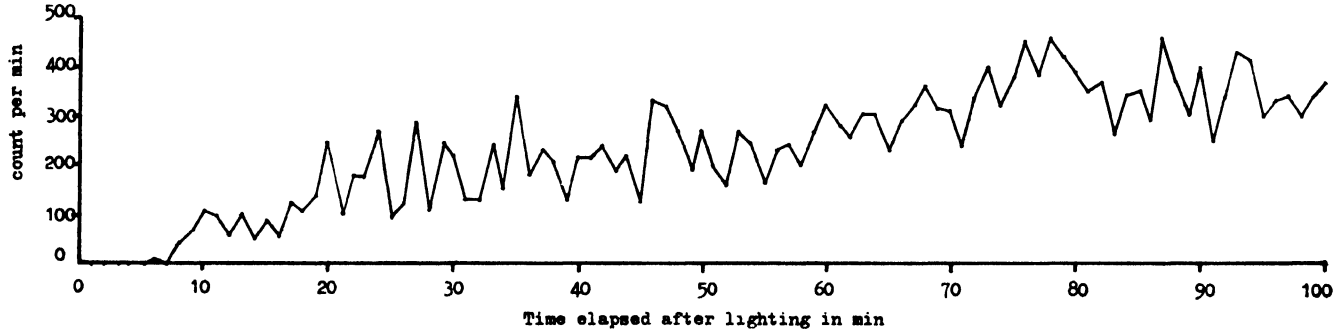

Fig 7. Echo counting of anchovy attracted by an underwater lamp

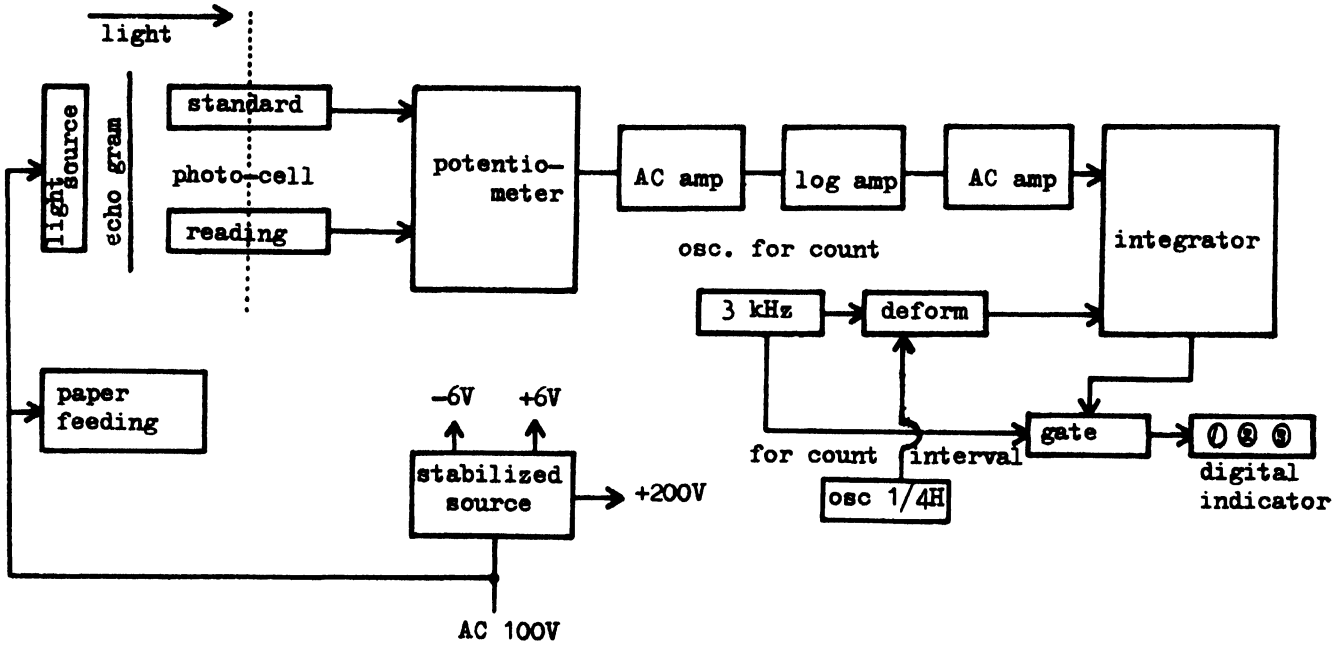

Fig 8. Block diagram of optical integrator for echogram

shifted up and down over the echogram and the width of its sensitive window can be also regulated manually for reading ranges, e.g. the headline height of a trawlnet. The standard phot-cell measures only the non-coloured part for comparison with the output of the reading photo-cell.

The parallel rays of the light source penetrate the echo chart, and reach the photo-cells. These transform light intensity into electric voltage which is connected to a potentiometer and then fed into the integrating circuit via a logarithmic main amplifier (fig 9).

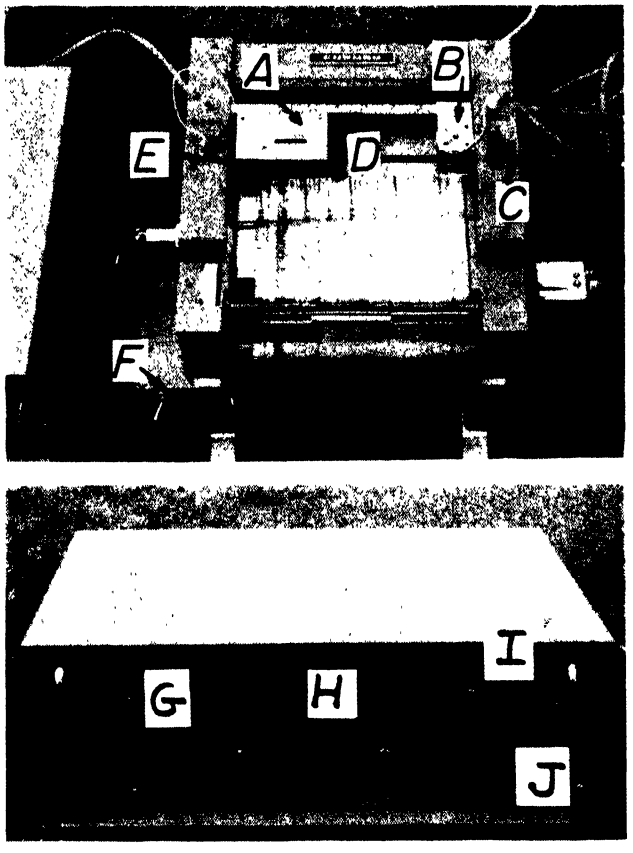

Fig 9. Optical integrator for fish school traces. Top: optical part. A = standard photo-cell, B = reading photo-cell, C = shifting screw of reading photo-cell, D = adjusting screw of sensitive window, E = light source, F = paper feeding motor. Bottom: integrating part. G = indicator reset switch, H = 3 digit indicator, I = potentiometer, J = zero adjuster of potentiometer

The colour density and dimensional area of echo traces are thus transformed into an index number of fish abundance. When the readings and integrations are repeated at a constant interval which is established by the paper feed speed the total integration of the readings of this system should correspond automatically to the total amount of marine animals distributed in the water.

Fundamental experiments

Fundamental tests were carried out on the reading stability and on the response to the colour density of several identical echo levels at minimum recordable signal level.

The reading for a saturated echo trace is stabilized at 1.5 hours after starting this system. The readings of 15 identical echo levels by 3 dB gave a linear interrelation with the actual echo levels between 12 dB and 33 dB, but no readings below 12 dB.

Several fish school traces which were obtained in Chijiwa Bay, were evaluated by the two methods of optical integration and planimeter in the laboratory. These results were compared with the direct echo countings of the fish school counter (fig 6). The comparative results are shown in Table 2.

TABLE 2. COMPARISON OF THREE METHODS FOR EVALUATION OF FISH SCHOOL

Fish school	A	B	C	D
Planimeter* (mm^2)	1350	1020	1286	930
School counter	951	789	845	713
Optical integrator*	1000	1156	822	628

Remarks: A, B without TVG; C, D with TVG.
*Average of 5 observations.

COMMENT

The results obtained up to now indicate that the following points must be considered in further experiments with fish counters in fisheries research.

There are three types of errors in fish counters caused by ship motions in rough seas:

Swinging of the sound beam due to rolling and pitching,

The production of air bubbles across the sound beam which induce attenuation of sound, and

Generation of acoustic noise.

To eliminate these effects the authors are planning to design a towed transducer. It should be completed by the end of 1970.

Individual fish can only be counted, provided they are recorded separately on the echogram. For fish school traces the counted number of echoes indicates only a relative value which varies according to density and dimensions of fish school. To estimate actual fish stocks from such countings conversion factors from the relative counting value to the absolute fish quantity are needed. This requires further study.

The readings of the optical integrator show some deviations which are caused by the saturation of colour density on echograms and by the irregularity in optical response of echo charts due to uneven quality of the surface. Especially since the readings of this system are not proportional to the echo level at a range of more than 30 dB, a circuit which has linear response to the colour density of the echo level is now being developed.

Acknowledgement

The authors thank Mr. H. Yamanaka and other colleagues of the Far Sea Fisheries Laboratory, Nansei and Seikai Regional Fisheries Laboratory of the Fishery Agency for their collaboration in this work.

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Experimental Measurement of Target Strength of Fish

K. Shibata

Détermination expérimentale de l'intensité d'echo ultrasonore des poissons

Des mesures d'intensité d'écho et de champ de réverbération ont été réalisées à 50 kHz et 200 kHz dans un bassin sans écho. L'influence de la taille du poisson, de la vessie natatoire et des autres viscères sur l'amplitude de l'écho et le champ de réverbération a été précisée. La réflection totale de la chair du poisson a été déterminée pour différentes espèces à partir de mesures des caractéristiques de la vitesse du son et de la densité de la chair du poisson. La comparaison des intensités d'écho calculées et observées ont montré une meilleure concordance avec la basse fréquence et des poissons relativement grande. Des mesures d'intensité d'écho effectuées en mer sur des thons congelés puis décongelés, au moyen d'un écho-sondeur de 28 kHz, ont bien coincidé avec les valeurs calculées.

Medida experimental de la fuerza del blanco que presentan los peces

En un depósito anecóico se han medido la fuerza del blanco y el coeficiente de refexión de la carpa dorada silvestre a 50 kHz y 200 kHz. Se describe la influencia del tamaño de los peces, de la vejiga natatoria y de otras vísceras en relación con la amplitud del eco y dicho coeficiente. Se determinó la reflectividad total de la carne de los peces de diferentes especies por medio de mediciones de la velocidad del sonido y de las características de densidad de la carne. La comparación de la fuerza del blanco, calculada y observada, del pez manifestó una mayor coincidencia con la menor frecuencia y con los peces de tamaño relativamente mayor. Las mediciones de la fuerza del blanco del atún congelado a bordo a baja temperatura, eviscerado y descongelado, con una ecosonda de 28 kHz coincidieron con los cálculos.

ACOUSTIC methods for fish stock assessment have shown the importance of ultrasonic wave reflection from fish, and also of the parameters of the echo sounders utilized for echo surveys of fishing grounds. Hashimoto (1953), Maniwa (1962), Cushing *et al.* (1963), Haslett (1964), Love (1968) have reported observations on the target strength of various fish. In this report some experimental results of target strength measurements of individual fish, including wild-goldfish, "Funa", are described.

Experimental measurements of target strength and back-scattering pattern were carried out with 50 kHz and 200 kHz on 206 wild-goldfish, *Carassius carassius* and *C. c. cuvieri*, in the anechoic tanks of the Faculty of Fisheries, Hokkaido University and Nagasaki University. The inner structure of all target fish was studied by soft X-ray photography.

Standard measurements of specific gravity were made for the fish flesh as well as for the whole fish body with the air bladder removed. Sound velocity in several kinds of fish was also estimated. The target fish was submerged in fresh water across the acoustic axis at a range of 100 cm from the receiving and transmitting transducers which were installed horizontally in the anechoic tank. The back scattering signal strength of the target fish was measured for the following conditions and positions: live fish under anesthesia, dead fish without air bladder and dead fish without air bladder and viscera; for the three positions see fig 1.

The long axis of the air bladder of "Funa" forms with the swimming axis an angle of about 10° (fig 2) which

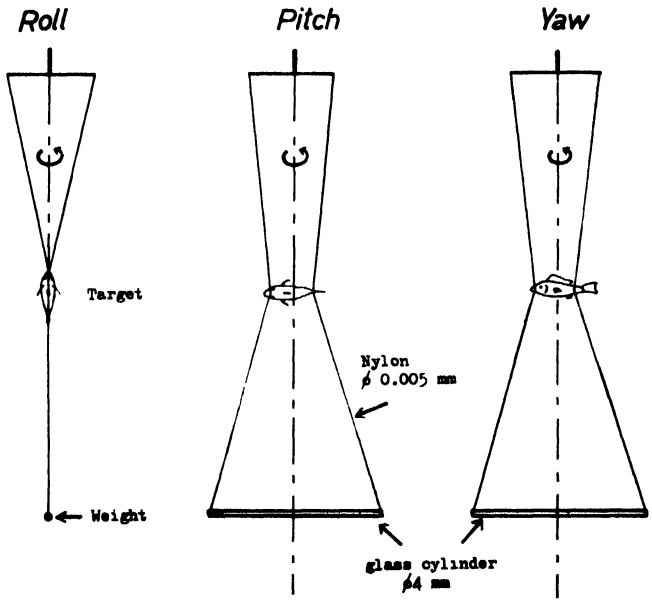

Fig 1. Positioning of the target fish in three aspects towards the transducers. The direction of the sound beam is normal to the plane of this drawing

affects the echo strength and the back scattering pattern, especially in the dorso-ventral direction of maximum signal. The dorsal maximum was observed at an angle of 10° head away from the transducers in the pitch plane (fig 1 and 3), as already reported by Midttun and Hoff (1962), the lateral maximum was 5° to 10° towards the

TABLE 1. AVERAGE DIMENSIONS OF DIFFERENT FISH COMPARED WITH OVERALL LENGTH OR BODY HEIGHT OF FISH

Wild-goldfish	*Goldfish*	*Stickle-backs*	*Guppies*	*Mackerel—common*	*Mackerel—jack*	*Sardines*
SL 0.81L	0.76L	0.84L	0.80L	0.9L	0.9L	0.84L
H 0.265L	0.205L	0.11L	0.20L	0.191L	0.22L	0.186L
B 0.151L	0.15L	0.113L	0.15L	0.13L	0.123L	0.123L
B 0.57H	0.62H	0.72H	0.72H	0.68H	0.56H	0.66H
W $0.014L^3$	$0.013L^3$	$0.011L^3$				

L = overall length of fish;
SL = standard length excluding caudal fin;
H = maximum height of fish;
B = the maximum width;
W = body weight.

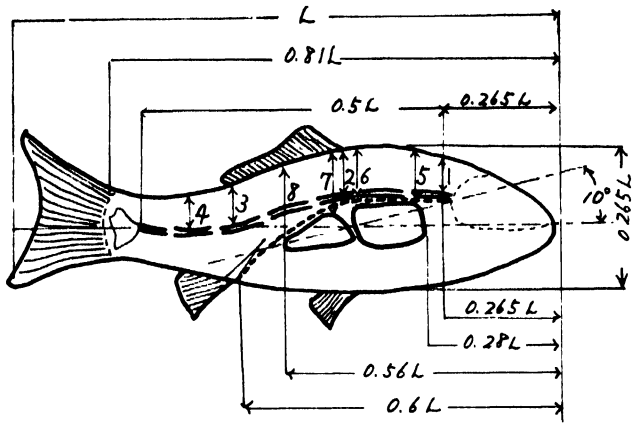

Fig 2. Scheme of the average dimensions of fish on which calculations of the signals returned from different parts can be based. All dimensions are expressed as functions of the overall length (L)

Dorsal to	*dimension 1*	*0.082L*
	,, 2	*0.091L*
vertebral	*,, 3*	*0.089L*
column	*,, 4*	*0.073L*
Dorsal to	*,, 5*	*0.098L*
	,, 6	*0.11 L*
air bladder	*,, 7*	*0.11 L*
	,, 8	*0.16 L*
Diameter of vertebral column		*0.015L*

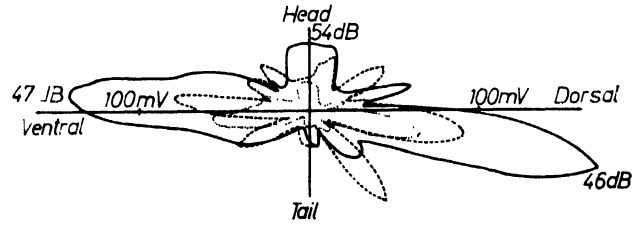

Fig 3. Acoustic back-scattering polar diagram of Funa in various positions in the pitch plane

Dimensions of target fish (see Table 1)

TL : 9.79 cm
SL : 7.86 cm
H : 2.42 cm
B : 1.29 cm
W : 12.2 grm

Solid line: live fish
broken line: fish body without air-bladder
dotted line: without air-bladder and viscera

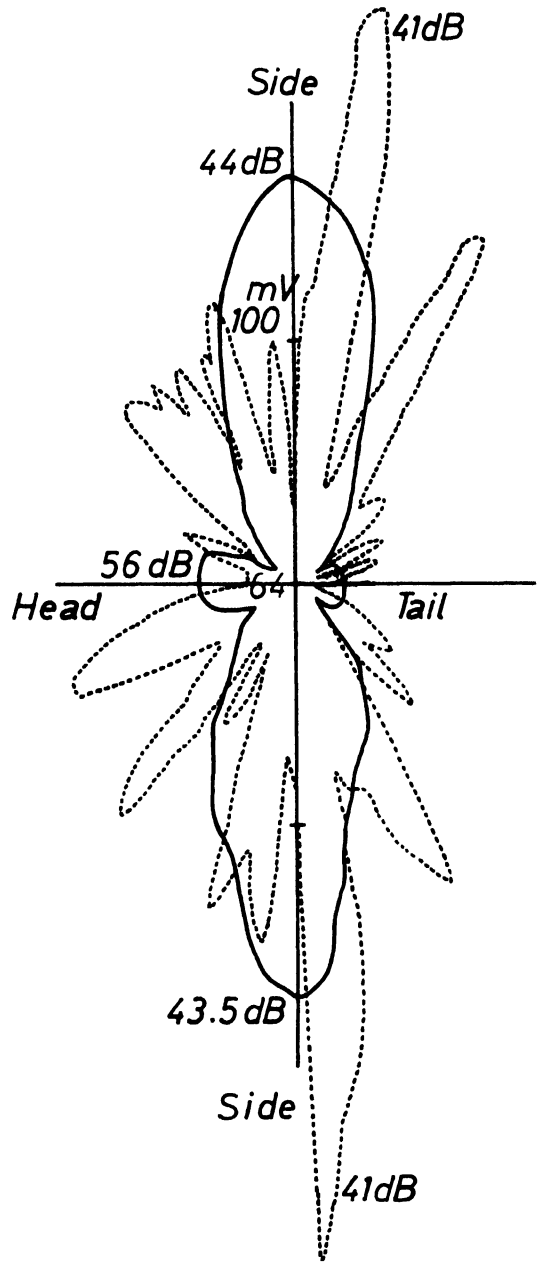

Fig 4. Acoustic back-scattering polar diagram of wild goldfish in the yaw plane

Solid line: 50 kHz, broken line: 200 kHz
TL : 8.17 cm (2.72 λ and 10.88 λ)
SL : 6.50 cm
H : 2.07
B : 1.17
W : 7.5 grms
Water temperature : 20.0°C

ventral side in the roll plane and also 5° to 10° towards the tail in the yaw plane (fig 4).

The target fish being supported in the tank on the acoustic axis, a back scattering polar diagram of the fish was obtained by measuring the echo strength for all directions, by rotation angles of 2.5°, 5° or 10° in the three orthogonal planes. In general the polar diagram shows complicated fluctuations with repeated maxima and minima, the number of lobes and the difference between maxima and minima increasing with the ratio of fish size to acoustic wave lengths (L/λ) (fig 5). The Rayleigh zone for ultrasonic reflection on the fish seems to correspond to $L/\lambda \leq 1$, which confirms the non-directional acoustic polar diagram of small fish of a length up to that of the acoustic wave.

Acoustic absorption and total reflectivity

The density of fish flesh varies between 1.04 and 1.09 with individual variation according to the size and part of the fish. The density of the body with air bladder removed was 1.045 to 1.10. Sound velocity through the fish flesh is 1,500 to 1,600 m per second (Tables 2 and 3).

At the common range of frequency of commercial echo sounders, acoustic absorption of fish flesh seems to be very small but it can be important for higher fre-

TABLE 2. ACOUSTIC CHARACTERISTICS OF FISH FLESH AT FREQUENCY OF 2 MHz

Name of fish	*Length overall* cm	*Density* g/cm³	*Sound velocity* m/s	*Total reflectivity*	*α* dB/cm	*Thickness of specimen* cm
Herring* *Clupea pallasi*	30.2	1.05	1527b	0.022	4.1	0.83
Bigeye tuna *Thunnus obesus*	125	1.09 1.085	1585a 1600b	0.060 0.062	2.9 3.0	2.08 3.69
Yellowtail *Seriola quinqueradiata*	28.5	1.063	1517b	0.025	1.5	0.84
Common mackerel *Pneumatophorus j. japonicus*	36.5	1.065	1539b	0.033	1.3	1.53
Sablefish *Anoplopama fimbria*	78	1.04	1511b	0.012	0.3	0.93
Sailfin sandfish *Arctoscopus japonicus*	24.1	1.045	1538b	0.023	0.4	0.71
Wild-goldfish** *C. carassius* spp.	18.7	1.045	1529b	0.038	1.7	0.89
Pink salmon* *Onchorhynchus gorbuscha*	53.5	1.07	1582a 1543b	0.046 0.037	2.2 0.82	4.44 1.20

Remarks:
(1) Density and sound velocity of sea water was assumed as 1.022 g/cm³ and 1500 m/s, and of fresh water as 1 g/cm³ and 1489 m/s.
(2) Asterisk indicates refrigerated specimens; double asterisk fresh water fish.
(3) a: Velocity of sound travelling in direction of fibres.
b: Velocity of sound travelling perpendicular to direction of fibres.
(4) Temperature of specimens: 19.5°C at pink salmon, 21°C at herring and sailfin sandfish, 22.3°C at wild-goldfish and 18.3°C at other fishes.

TABLE 3. ACOUSTIC CHARACTERISTICS OF FLESH OF FISH CAUGHT BY TRAWLS IN THE EAST SEA, AT FREQUENCY OF 2 MHz

Name of fish	*TL* cm	*W* g	*Sound velocity* m/s	*Density* g/cm³	*Total reflectivity*	*Absorption* (1) dB/cm	(2) dB/cm
Common mackerel *Pneumatophorus j. japonicus*	35.0	545	1540	1.061	0.032	0.8	0.8
Grouper* *Sayanara sp.*	41.5	1200	1520	1.054	0.022	0.3	1.0
Yoroiitachiuo* *Hoplobrotula armata*	46	707	1547	1.052	0.030	0.3	0.3
White croaker* *Argyrosomus argentatus*	36.5	670	1543	1.053	0.029	0.3	0.4
Gurnard* *Chelidonichthys kuma*	43	865	1547	1.053	0.030	0.9	1.1
Dogfish* *Squalus* sp.	49	560	1567	1.062	0.041	0.4	2.2
Kuromutsu* *Scombrops boops*	33	425	1545	1.052	0.029	0.7	0.8
Porgyfish* *Gymnocranius griseus*	27	360	1540	1.049	0.026	0.5	0.7
Ara* *Niphon spinsus*	36	515	1565	1.051	0.035	0.6	0.7
Stargazer* *Gnathagnus elongatus*	32.5	590	1545	1.054	0.030	0.6	0.8
Jelly fish *Stomolophus nomurai* (about 100 cm in diameter)			1524	1.027	0.010		

Remarks:
(1) Asterisk indicates demersal fish.
(2) Column (1) shows absorption loss in fish flesh excluding skin.
(3) Column (2) shows absorption loss in fish flesh including skin.

quencies or larger fish. This tendency is particularly pronounced in fish with hard scales or skin (Table 3).

The total reflectivity of fish flesh determined from sound velocity and flesh density fluctuates from 0.022 to 0.062 and is mainly in the range of 0.025 to 0.035, values for demersal fish being smaller than those for pelagic fish.

The characteristics of back-scattering strength from fish in a range of 1λ to 20λ in overall length are approximately the same as for a short cylinder. Empirical average equations derived from various fish were found to be:

(i) dorsal maximum:

$$Ts = -Lp = 28.0 \log L - 8.0 \log \lambda - 67.4$$

(ii) lateral maximum:

$$Ts = -Lp = 25.7 \log L - 5.7 \log \lambda - 63.8$$

Ts = target strength in dB;
Lp = reflection loss;
L = overall length of fish in cm;
λ = sonic wave length in cm (fig 6)

for Funa with $1 \leq L/\lambda < 20$ at 50 kHz and 200 kHz and for tuna with $10 < L/\lambda < 30$ at 28 kHz.

The amplitude of the back-scattering signal from a fish is basically the vector sum of the echo amplitude from each part of the body (Haslett, 1964). The estimated target strength of fish is given by the following equation:

$$Ts = 10 \log \frac{\sigma_f + \sigma_{ab} + \sigma_v}{4\pi(100)^2}$$

σ_f: back-scattering cross section of fish body after removal of the air-bladder and vertebrae

$\sigma_{fD} = \frac{B\pi \overline{SL^2}}{\lambda} \overline{TR^2}$: dorsal aspect, B = body width

$\sigma_{fS} = \frac{2\pi H \overline{SL^2}}{\lambda} \overline{TR^2}$: lateral aspect,

H = body height,
TR = total reflectivity

σ_{ab}: back-scattering cross section of the air-bladder of Funa

$$\sigma_{ab} = \frac{2\pi\, 0.033\, (0.25)^2\, L^3}{\lambda}$$

σ_v: back-scattering cross section of vertebrae of Funa. L = length overall of fish

$$\sigma_v = \frac{0.015\pi\, (0.5)^2\, L^3}{\lambda} (0.26)^2$$

Calculated and observed target strength often coincided, in particular at 50 kHz. The highest agreement at 50 kHz was found within ± 3 dB for the maximum dorsal and the maximum lateral signal. However, the value observed for smaller fish was larger than the calculated one. At 200 kHz, the number of lobes in the acoustic polar diagram was greater than at 50 kHz in fish of the same size, so that readings taken at 200 kHz greatly varied with an error of a few degrees on the suspending angle of the target fish. Therefore such large difference between the calculated and observed target strength might be described as a minute difference in the supporting system of fish body. If the dimension, weight and density of fish were known, the estimation

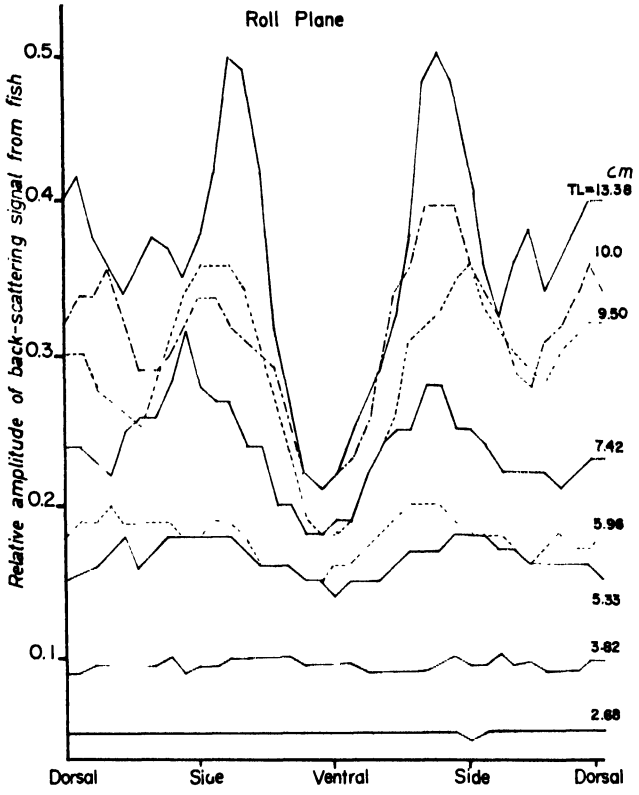

Fig 5. Acoustic back-scattering diagrams of Funa of various lengths (wavelength: 3 cm)

of the target strength of a fish up to 20λ in acoustic length, with the frequency up to 200 kHz, could be possibly obtained with a considerably higher accuracy (± 2 dB) which is good enough for practical use.

Influence of fins, air bladder etc.

In the echo strength from a fish the influence of various fins was estimated as neglible. Standard length of fish does not include the caudal fin which composes only 2 per cent of the echo amplitude in the acoustic determination of live fish.

The overall average signal amplitude from a fish rotated 360° was determined by a series of measurements for all above-mentioned positions and conditions, and the relation to the overall average signal amplitude of live fish was established. The air bladder resection reduced the average echo amplitude by 43 per cent in the roll plane (observation on 140 live "Funa") and by another 22 per cent for further resection of other viscera. Since body widths and visceral contents vary according to feeding and spawning conditions they may consequently cause significant fluctuations of target strength.

Target strength of tuna

Field experiments on target strength were carried out in 1968. A commercial echo sounder was operated at 28 kHz with a pulse length of 2.5 ms. Twenty-five tuna, thawed after deep freezing, with air bladder, viscera and gills resected were used as target fish. Calculation of target strength for fresh fish showed good coincidence with the measured values except for thawed tuna with an artificial air bladder which showed a slightly lower value than the calculated one (fig 6).

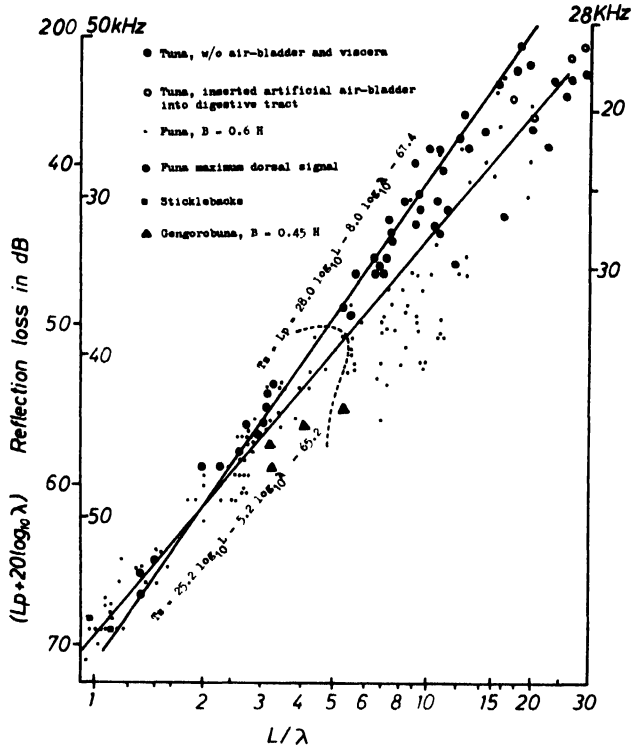

Fig 6. Reflection loss of fish in dorsal aspects with regard to fish size

Acknowledgement

Assistance from Prof. M. Ishida, Faculty of Fisheries, Hokkaido University, is gratefully acknowledged.

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Preliminary Results of Acoustic/Fishing Surveys in West African Coastal Waters

D. F. S. Raitt, G. F. Losse, W. Schmidt, I. Hoff

Resultats preliminaires de prospections acoustiques/halieutiques dans les eaux de l'Afrique de l'Ouest

Des prospections acoustiques/halieutiques sont effectuées dans les eaux côtières de l'Afrique de l'ouest dans le cadre d'un ensemble de projects du Programme des Nations Unies pour le Développement/Fonds spécial (PNUD/FS) pour l'étude et la mise en valeur des ressources en poissons pélagiques de cette zone. La FAO est l'agent d'exécution de ces travaux et les efforts partent essentiellement sur la détection du poisson et l'estimation de l'abondance par des méthodes acoustiques. Le présent rapport décrit les activités entreprises dans le cadre de l'enquête régionale sur les pêches, ainsi que le matériel acoustique et les engins de pêche utilisés. Les résultats obtenus jusqu'à présent indiquent que les zones les plus riches en petits poissons pélagiques se trouvent en Guinée, au nord et au sud du Gabon. Les principales espèces pélagiques groupées en bancs, au point de vue importance industrielle, sout diverses espèces de carangidés (chinchard), le maquereau "atlantique" (*Scomber japonicus*) et les sardinelles *Sardinella aurita* et *S. eba*. Le comportement de ces espéces, notamment au crépuscule et à l'aube, fait que leur répartition est très différente de jour et de nuit et, par conséquent, les méthodes de capture applicables ne sont pas toujours les mêmes. Un succès considerable a été remporté par le chalutage pélagique avec netsonde, sur couches diffusantes, de nuit. Le mélange des espèces dans les eaux tropicales rend extrèmement difficile l'identification spécifique des écho traces individuelles. On espère pouvoir tirer pleinement parti, en 1970, du matériel acoustique installé à bord des navires de pêche, et des mesures préliminaires d'intensité de cible ont été déjà effectuées individuellement sur *Sardinella*, en vue de dénombrer les échos individuels à l'aide de l'intégrateur. Les difficultés soulevées par l'intégration des échos renvoyés par un seul poisson appartenant à une espèce donnée restent encore considérables.

Resultados preliminares de los estudios acustico/pesqueros que se efectuan en las aguas costeras del Africa occidental

En las aguas costeras del Africa occidental efectuan estudios acústico/pesqueros como parte de un plan del Programa de las Naciones Unidas para el Desarrollo (Fondo Especial), encaminado a estudiar y explotar los recursos de peces pelágicos en dicha zona. La FAO es el organismo de ejecución de estos estudios, y se está concediendo gran importancia a la localización de peces y a la estimación de su abundancia mediante métodos acústicos. En este informe se describe la labor del Estudio Pesquero Regional así como del equipo acústico y los artes de pesca que se están empleando. Hasta ahora los resultados indican que las principales zonas de abundancia de peces pelágicos pesqueños se encuentran al norte de Guinea y al sur del Gabón. Los principales cardumenes de peces pelágicos de importancia industrial son varias especies de carángidos (jureles), la caballa "Atlántico" (*Scomber japonicus*) y las sardinas *Sardinella aurita* y *S. eba*. El comportamiento de estas especies, especialmente durante el crepúsculo y el amanecer, hace que su distribución sea completamente distinta de día y de noche, por lo que los peces no se pueden pescar siempre con los mismos métodos. Se han obtenido resultados muy satisfactorios practicando de noche la pesca petacica con "netsonde" en las capas de dispersión sónica. La mezcla de especies en las aguas tropicales hace extremadamente difícil la identificación concreta de los ecogramas individuales. En 1970 se espera obtener todo el potencial del equipo acústico instalado en el barco, y se han hecho ya las mediciones de la fuerza del blanco de *Sardinella* individual para contar los ecos individuales empleando el integrador. Siguen siendo considerables las dificultades de integrar los ecos de los peces de una especie determinada.

THE Regional Fisheries Survey in West Africa (RFS) is part of United Nations Development Programme (Special Fund) projects for the survey and development of pelagic fish resources along the West African coast. National projects have been established in Senegal, Sierra Leone, Ivory Coast and Congo (Brazzaville), and in addition work is being coordinated with the Fisheries Project in Ghana.

Principal objectives are to evaluate the abundance and differential distribution of the pelagic fishes of the region, particularly *Sardinella* and associated species, in relation to the environment.

The operational area is roughly from Cape Blanc, Lat 21°N, to the Congo River, Lat 6°S, i.e. covering the waters off the coast of all West African countries from Mauritania to Congo (Brazzaville). The RFS is not only attempting to fill in the gaps between the national projects, but is extending the area they investigate into deeper water.

A vessel has been chartered from Tromsøe in Norway. She is 38.1 m (125 ft) overall *Thue JR* built in 1964 as a stern trawler/long-liner. In 1968 she was converted for purse seining while still retaining the facility to trawl.

Strong emphasis is being placed in this scheme on fish detection and estimation of abundance by acoustic methods. All vessels have been fitted with standardized equipment and the echo sounders have been intercalibrated. Early in 1968 an Acoustic Standardization Training Scheme was held in Abidjan to coordinate methods of working and interpreting results. An acoustic log sheet was designed for recording data.

This report gives preliminary results from the first year of survey.

ACOUSTIC EQUIPMENT

The basic approach is by large-scale acoustic surveys and fishing operations to build up a picture of the relative abundance of pelagic fish between different areas. This information is supplemented whenever possible by direct knowledge of commercial catches, and catching rates. In addition, equipment has been installed which should lead to more direct measurements of absolute abundance.

The sonar installation consists of the Simrad SB2, a powerful sonar with a maximum range of 2,500 m (2,750 yds). The transducer is tiltable from 5° above to 45° below the horizontal. A gyro repeater is fitted which greatly facilitates the sonar observer giving exact bearing to the target.

Echo sounders

There are two Simrad Scientific Sounders at 38 kHz and 120 kHz (Models EK38A and EK120A respectively), plus a tape recorder, precision depth recorder, oscilloscope, echo-integrator and calibration equipment.

The Scientific Sounder is a new type of echo sounder, especially designed for fishing research, which is fully transistorized and has printed circuits. The principal advantage of this instrument is the facility of time varied gain (TVG). This feature automatically compensates for the geometrical loss of acoustic power in the sound beam, with depth. Thus, with this echo sounder, the signal strength from a single fish at 300 m (about 165 fm) depth will be identical to that received from the same fish at 10 m (about 5 fm). The TVG function greatly facilitates the calculation of target strength from individual targets. The receiver features a number of other special functions including white line, dual gain, contour line, etc. In addition to a manual marker, there is a nautical mile marker triggered by the ship's log.

The oscilloscope is the Hewlett-Packard 141A storage scope. In simpler models the deflections occur only as a short flash on the screen. When calculating target strength from single fish echoes it is necessary to read the beam deflections on the oscilloscope. With a storage scope it remains on the screen between soundings, thus providing sufficient time to accurately read off the value of the deflection. The scope is also used in the calibration of the echo sounder and sonar.

The echo integrator is an instrument for the automatic logging of echo signals received by the sounding equipment. The instrument consists of a time control unit, an integrator and a recorder with temperature-sensitive paper. It is coupled to the amplifier in the selected echo sounder and receives the same kind of electrical echo pulses as the stylus in the recorder for the echo sounder. The control unit enables one to select a certain depth range for the integration, say from 20 to 50 m (about 10 to 25 fm). The integrator then receives and adds together all electrical echo pulses from this depth range. If the target strength of the fish being recorded is known, it is possible to calculate the approximate total number. If, on the other hand, the number of single traces from this depth range are known, one can calculate the average target strength provided the individual targets can be identified.

The principal use of this instrument, so far, has been the investigation of "scattered fish". Dragesund and Olsen (1965) obtained estimations of O group fish from the Barents Sea and more recently, Midttun and Nakken (1968) used the integrator for mature cod. To obtain individual fish counts by this method it is necessary for the fish to be thinly scattered. They must be identified, probably by fishing, and some estimate must be available of the individual target strength. Much work remains to be done before the full potential of this instrument is realized. Already it has added greatly to the knowledge that can be obtained with the acoustic installation on the RFS vessel.

FISHING GEAR

Purse seine

The original seine was of Norwegian design and manufacture: 250 fm long and 52 fm deep (about 460 m × 95 m), netting nylon, 20 mm (0.78 in) stretched mesh, 10 mm bar, (0.39 in), hung in 5 horizontal panels of 10 fm (18 m). A 15 ft (4.5 m) fibre-glass Basboat, powered by a 45 hp Volvo Penta gasoline engine, is used to keep the ship out of the net when pursing and hauling. Since most of the surface schools available for seining have been found in shallow water, the seine has been adjusted to 30 fm (about 55 m) by taking out two of the panels. Purse seining within the framework of the project has

not so far been very successful—due to several factors, such as the general unfamiliarity of the crew with this type of fishing, the high reaction speed of tropical pelagic fish schools to an approaching vessel and strong surface currents. With more experience and skill better results might come.

Midwater trawls

The vessel has a Wichmann 6 ACAP two-stroke diesel engine developing 900 hp at 350 rpm so there is ample power for towing quite large trawls. The two midwater trawls currently being used are Engel nets. The larger has a 1600 mesh circumference at the mouth opening with meshes of 200 mm (7.8 in) stretched and is finished with 6 m² (about 64.5 ft²) Süberkrüb otter boards. There is also a smaller trawl of 1570 meshes, 160 mm (6.2 in) stretched. Both nets have cod-end meshes of 25 mm (1 in) stretched and an Atlas net sonde with headline transducer is employed. This has proved extremely satisfactory giving regular catches in excess of 5 metric tons per hour when fishing on scattering layers at night.

Demersal trawl

A high-opening Engel demersal trawl has been used to assess the possibility of catching pelagic fish close to the bottom. The net has 530 meshes circumference (200 mm (7.8 in) mesh stretched) and cod-end meshes of 32 mm (1.2 in) stretched. The average catch of pelagic species with this gear has been very low.

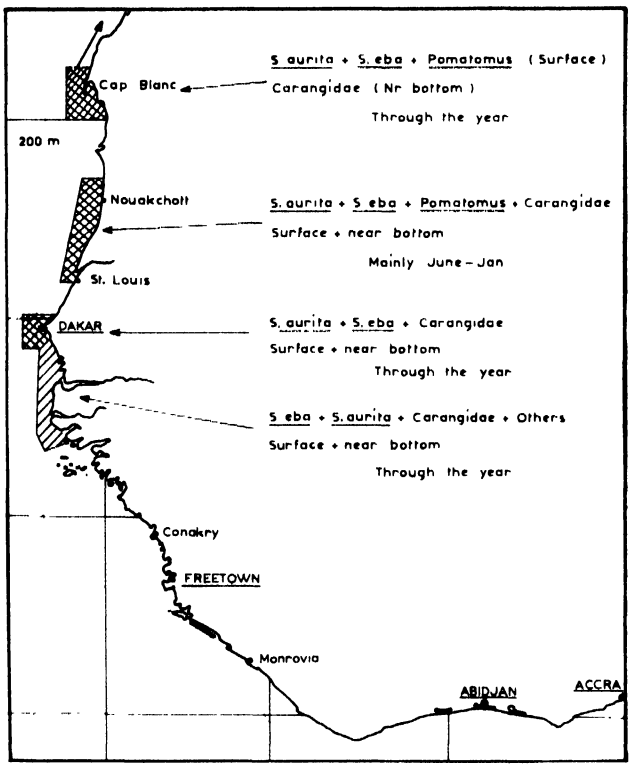

Fig 1. Distribution of principal areas of pelagic fish abundance, Cap Blanc to Abidjan

PRELIMINARY RESULTS

The present survey data do not confirm the existence of large pelagic resources of major industrial importance in the Gulf of Guinea (i.e., Cape Vergas to Cape Lopez). The stocks of pelagic fish available for commercial exploitation are fairly limited and concentrated in only a few areas. These are the regions where upwelling takes place regularly every year. The largest and by far the most important area is off Senegal/Mauritania where considerable quantities of *Sardinella*, horsemackerel (*Caranx*, *Trachurus*) and other species are found throughout the year. Numerous trawlers from Ghana, Russia, Italy, East Germany, etc., are already fishing in these waters and the fishing effort seems to be increasing from year to year. The area can be roughly divided into three major regions (see fig 1):

(a) off and north Cap Blanc (Spanish Sahara)
(b) between Nouakchott and St. Louis (Mauritania), and
(c) off and south of Dakar down to the Casamance Estuary (Senegal).

The concentrations of pelagic fish, off and north of Cap Blanc, appear to consist mainly of *Sardinella* and horsemackerel. Apart from these, little tuna (*Euthynnus*) and Tassergal (*Pomatomus*) can occasionally be caught as a by-catch, depending upon the existing water temperature. The fish are found both inshore, from about 8 m (about 4 fm) and offshore down to about 100 m (about 50 fm). During the day, *Sardinella* schools very often appear right at the surface and can be caught with a purse seine. At night when the fish are dispersed in a scattering layer they can be fished with a midwater trawl.

The fish concentrations between Nouakchott and St. Louis are mainly found in shallow water between 20 to 50 m (about 10 to 25 fm) and in deeper water towards the edge of the continental shelf. They consist of *Sardinella* and Carangid species. In addition, *Pomatomus* are frequently caught. *Anchoviella* also occur in this area, sometimes in rather large quantities. The fish are not found throughout the year in the same quantities since they seem to migrate to the north, and to the south, when upwellings change the hydrographic conditions (particularly temperature).

In the third area (off and south of Dakar) industrially exploitable fish concentrations are found throughout the year. Off Dakar these consist mainly of *Sardinella* and carangids but, towards the south, there is an increase in the total number of different species comprising the population.

Acoustic and surface observations, combined with fish catch data, have shown that scattering layers at night generally consist of numerous species available to midwater trawling at the same time and place. Off the major river estuaries of Portuguese Guinea and Senegal, scattering layers include a large component of small fish of little industrial value, except perhaps for reduction purposes. The most prominent species include the carangid, *Vomer*, and the semi-pelagic fish, *Brachydeuterus auritus*. In this area *Sardinella eba* and *S. aurita* represent a minor component (by-catch) of night catches. It is believed that the *Sardinella* are dispersed very close to the surface at night and are therefore mainly caught when hauling. This has in part been substantiated by the

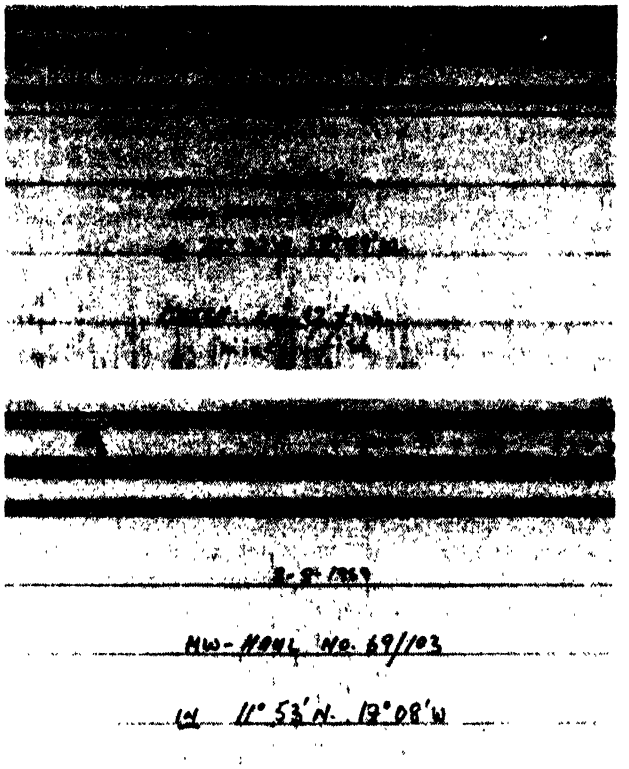

Fig 2. Top: echo trace obtained off the Casamance River mouth, Senegal, 6 August 1969, 2000-0100h, depth 18 m. Catch 5 metric tons/h, midwater trawl. Bottom: Ditto. 8 August 1969, 1600–1800 h, depth 20 m. Catch 1 metric ton/h, midwater trawl

frequent occurrence of small quantities of *Sardinella* trapped in the wing meshes of the net. Figures 2a and 2b show typical echo traces obtained in very shallow water off the Casamance River mouth (less than 20 m, about 10 fm), where catches of 5 tons and 1 ton per hour were made with a pelagic trawl. The catch, however, was of very mixed small fish.

In general, it can be said that in the north scattering layers consist of relatively few, but commercially important, species and, south of Dakar, of a large mixture of species with a relatively high industrial "trash fish" component.

As regards fish concentrations of commercial value, the entire shelf between the Cacheu River and Pointe Noire (Congo Brazzaville) appears to be very poor indeed (see fig 3). This does not mean that there are no fish at all, but the quantities are too small and scattered to interest big fishing vessels. There are two small areas, however, in which rather good catches can be made, although only for a few months in each year. The first one is off Takoradi, west of Accra in Ghana, where fishing vessels have recorded good catches of *Sardinella* and carangids, mainly in March/April in a depth of about 60 to 90 m (about 30 to 50 fm) on the bottom. The season appears to end about September/October.

The second area is off, and south of, Cap Lopez, where, in the hot season (from March to April and also in October), adult *Sardinella aurita* have been found in commercial quantities in depths between 70 to 100 m (about 35 to 50 fm). The fish appear to migrate from the south, concentrating in the cooler and deeper water

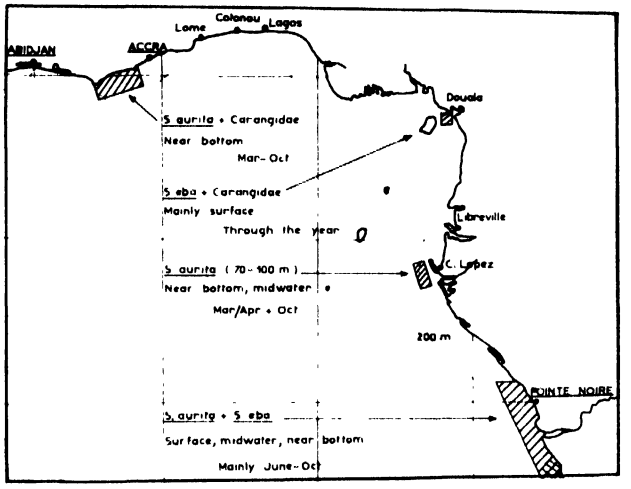

Fig 3. Distribution of principal areas of pelagic fish abundance, Abidjan to Pointe Noire

off this limited area. They keep close to, but clear of, the bottom, and can be caught with a midwater trawl.

Just as large quantities of commercially important fish occur in the northern upwelling area (Mauritania/Senegal) as they do in the south (Congo/Angola) where there are almost similar hydrographic conditions. Since the greater part of this southern region is beyond the scope of the RFS, no detailed investigations have been made there so far.

FISH BEHAVIOUR NOTED

Sardinella: In general, *Sardinella* in West Africa are concentrated in schools during day and dispersed in scattering layers at night. However, it depends upon the species, the age of the fish, and, particularly, upon the environmental hydrographic conditions, to what depth these schools descend during the day and how close to the surface they disperse at night. It is well documented, for example, that big adult *Sardinella aurita* often prefer a water temperature which does not exceed 18° to 19°C (65° to 68°F) and also a high salinity. Schools consisting of big *S. aurita* are therefore often found in the hot seasons in deeper water (approximately 70 to 90 m (about 35 to 45 fm)), more or less close to the sea bed. However, if the surface temperature is low, these schools occur right at the surface in shallow water. *Sardinella eba*, however, is an inshore species with a fairly high salinity tolerance and appears to prefer warmer water. Concentrations are found in shallow water, normally less than 40 m (about 20 fm), particularly in the warm seasons and in areas within the influence of the river outflows (Cameron River mouth, Gambia, Casamance, etc.). They form schools by day, often right at the surface. These schools disperse at night.

Good sonar contact

It has frequently been observed that in warm shallow water conditions schools of *S. eba* gave rather good sonar contacts by day but no recordings on the echo sounder. Even at night the sounder hardly showed any scattering layers because both schools and scattered fish were too

close to the surface—in fact above the transducers. Trials with the mid-water trawl at night off Douala yielded catches of about 0.4 tons/h consisting of *Sardinella eba*, *Ilisha* and several other pelagic species. To detect these fish, a towed body paravaning out of the ship's wake with a transducer sounding upwards, would appear to be essential.

Although *S. eba* is often found in water exceeding 27°C (81°F), dense concentrations were observed off Cap Blanc in October 1969 in shallow water less than 30 m (about 15 fm) where the temperature was only about 18°C (65°F). These fish measured 20 to 30 cm (8 to 12 in) total length and they occurred together with *S. aurita* of a similar size range. The quantities and proportions in the catches made both from schools (day) and from layers (night) were about equal.

Some echo traces associated with fairly pure catches of *S. eba* are shown in figs 4a and 4b. At 1430 h quite dense schools were recorded. After dark a scattering layer near the surface yielded 85 per cent *S. eba*. The lower half of fig 4b represents the netsonde recording.

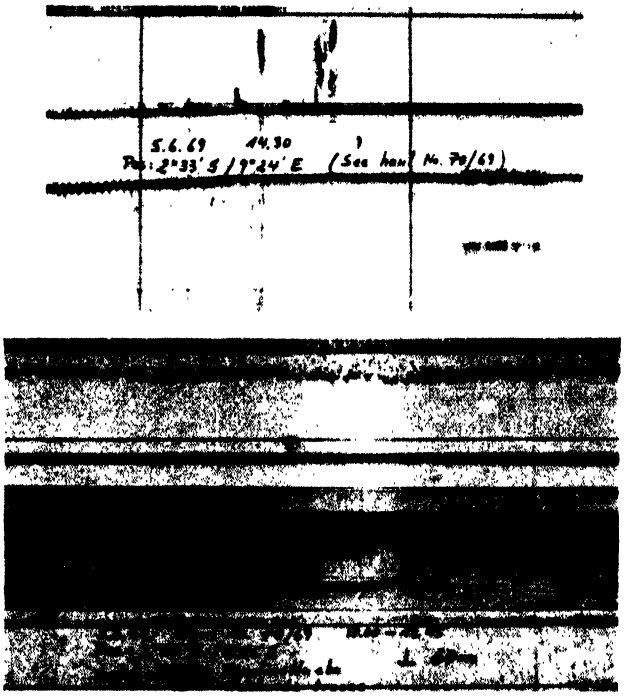

Fig 4. Top: South of Cap Lopez, Gabon, 5 June 1969, 1430 h, depth 60 m. Bottom: Ditto. 5 June 1969, 1800–1945 h, depth 60 m. Catch 0.25 metric ton/h, midwater trawl

Dusk and dawn migrations

At dusk and dawn rapid change occurred in the behaviour of *Sardinella*. After dusk schools disperse quickly and form a "B" type scattering layer of single fish. (See scale in Hoff and Raitt, 1969.) If schools are in deeper water close to the sea bed during the day, an upward migration takes place which may be very rapid—fish come up from 60 m to 2 m (about 30 fm to 1 fm) within 5 min. At dawn the scattered fish again form schools which either descend to the sea bed rapidly or remain surfaced.

This diurnal change in the behaviour of *Sardinella* and other commercially important fish, e.g., *Scomber*, appears to be a regular phenomenon when the nights are relatively dark. During the full moon period, however, it has been observed on several occasions that fish may not disperse but remain schooling near the surface at night.

Marchal (Personal Communication), however, reports that in shallow water off Ivory Coast, *S. eba* school at the surface when there is no moon and good purse seine catches can be made by observing the phosphorescence.

Other species

Other species of commercial importance also show vertical dusk/dawn migrations and form schools by day and scattering layers at night. Some of these are semipelagic species, e.g. *Trachurus*, *Caranx*, *Brachydeuterus*. Normally, these species stay on the bottom during the day, well separated from *Sardinella* schools, but mix with them at night in the scattering layers.

The scattering layers, therefore, apparently consist of true pelagic species and fish which are demersal during the day. This was well demonstrated by catches during the day and at night off Cap Blanc in October 1969. Two midwater trawl catches in the same geographical area show the different composition of species by day and at night. The day catch (69/137) resulted in 1.3 metric tons/h consisting of pure *Sardinella* (75 per cent *S. aurita*, 25 per cent *S. eba*). The night catch (69/140) in the scattering layer resulted in 3.3 tons/h and consisted of 42 per cent *Sardinella* and 48 per cent carangids (32 per cent *Trachurus* sp., 26 per cent *Caranx rhonchus*). Hence, the distribution and intensity of layers at night cannot be directly compared with the distribution and abundance of schools during the day. Examples of traces obtained at this time are shown in fig 5.

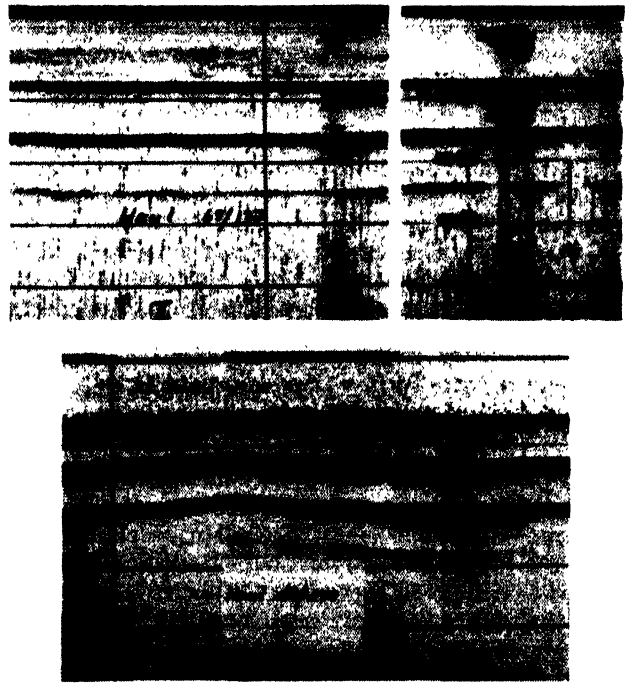

Fig 5. Top: Off Cap Blanc, Mauretania, 31 October 1969, 1200–1400 h, depth 40 m. Catch 1.3 metric ton/h, midwater trawl. Bottom: Ditto. 1 November 1969, 2000–2130 h, depth 30 m. Catch 3.3 metric tons/h, midwater trawl

Rather different results were obtained off Mauritania in April 1969. The echo traces are shown in fig 6. During the day schools near the bottom were recorded and a Ghanaian trawler fishing in the area recorded 80 per cent *Caranx*, 10 per cent *Sardinella* and 10 per cent *Trichiurus* in a 10 ton catch with the bottom trawl. The centre echo trace (6b) shows the schools rising at 1900 h and finally (6c) a midwater trawl haul on the scattering layer at 2000 h yielded 83 per cent *Caranx*, 11 per cent *Trichiurus* and mixed *Sardinella* and *Scomber* in a 2.5 ton catch. The same proportions as in daytime.

On several occasions dusk/dawn migrations were also observed on pelagic echo traces at the edge of the shelf or in canyons sounding 200 to 350 m (about 100 to 180 fm). Off Cape Lopez and off Mauritania these traces were frequently detected and they could be very dense showing blocking on the echo paper. By day the traces were approximately 150 to 250 m (about 75 to 130 fm) deep and ascended very rapidly at dusk, within 10 to 15 min, to only 40 to 60 m (about 20 to 30 fm) below the surface. All hauls made with the midwater trawl resulted in catches of small myctophids (2 to 5 cm) (about 1 to 2 in). Although these traces were very dense, they showed considerable differences to similar traces of fish of commercial interest. Particularly at night the resultant scattering layer was not a "B" type layer but a fine grain "A" layer, although a very dense one.

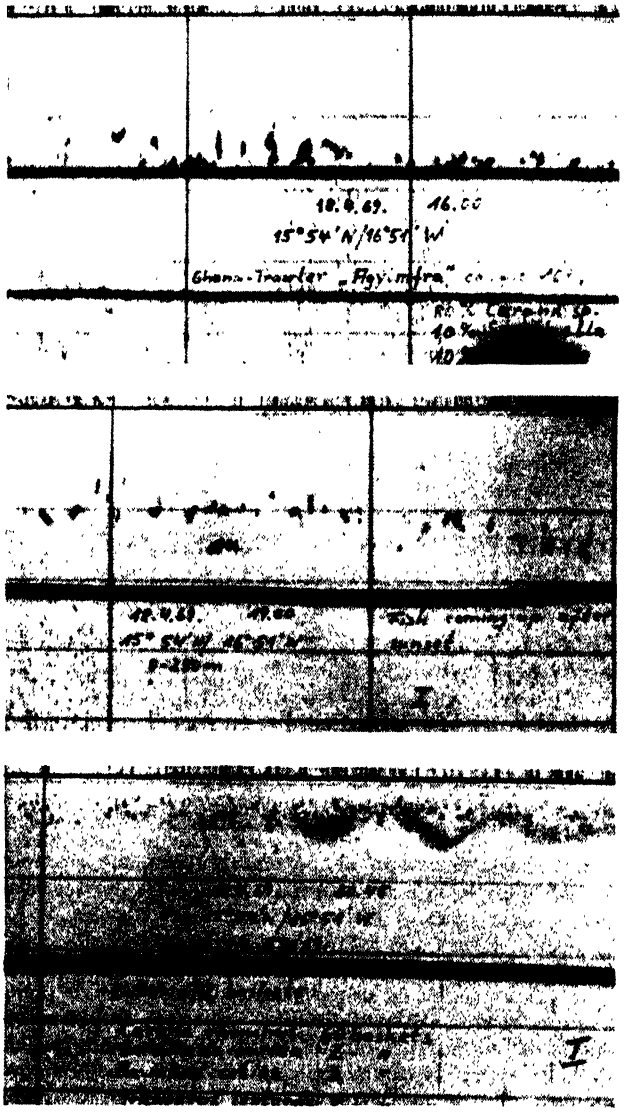

Fig 6. Top: Off St. Louis, Senegal, 18 April 1969, 1600 h, depth 80 m. Catch by commercial trawler 10 metric tons/h, bottom trawl. Middle: Ditto. 18 April 1969, 1900 h, depth 100 m. Bottom: Ditto. 18 April 1969, 2045 h, depth 110 m. Catch 2.5 metric tons/h, midwater trawl

PROBLEMS IN IDENTIFYING ECHO TRACES

Although the available knowledge on the biology and behaviour of tropical fish species has increased considerably in the last few decades, many problems still remain unsolved. One of these is the identification of individual echo traces. In West African waters, for example, where industrial fishing is developing steadily, no attempts have been made so far to eliminate the uncertainty of fishing operations by identifying the various species present before shooting the net.

It would greatly facilitate the work of the acoustic researcher if individual echo patterns could always be definitely assigned to different fish species. This is not possible, however, as different species can have the same schooling patterns and the behaviour of any one species can change from area to area and at different seasons.

Cushing (1957) has discussed this whole problem in some detail, but the hope still seems to linger amongst biologists that the echo sounder is an accurate discriminator of fish species. Unfortunately, this is not true. In the case where, for example, two very distinct forms of trace are encountered during one research cruise, each of which is associated with predominant catches of two different species, it is probably safe to analyse the records for that cruise accordingly. However, it would not be advisable to assume that all future traces of these types could be so assigned.

Unfortunately, there is no real precedent, or records of earlier experience in West Africa. The RFS has worked on this topic during acoustic surveys, combined with fishing operations, to obtain detailed knowledge in detecting and identifying fish schools, their distribution, abundance and migrations.

The greatest problem is the considerable mixture of species in tropical waters. Particularly in shallow water from 10 to 50 m (about 5 to 25 fm) depth, and near estuaries, numerous species, such as *Vomer*, *Trachurus*, *Caranx* and *Brachydeuterus* are found together with *Sardinella*. This mixture makes it virtually impossible to identify traces by echo sounder or other acoustic instruments. In addition, in estuaries, where dense schools may be detected by the echo sounder and sonar regularly during the day and scattering layers are to be found at night, both schools and scattered fish are often very close to the surface and even when the sonar obtains good contacts, it is extremely difficult to catch the fish. Surface schools could be caught with a very shallow purse seine, but this equipment is not available on board the RFS vessel. It is very difficult to catch them during the day with the midwater trawl. Although it is possible to tow the net near to the surface with only 50 to 60 fm warp and a speed of about 4 kn the fish are very active and avoid

the net. At night, when the fish are scattered and slower, samples can be obtained but then the species are even more mixed and it is not possible to get an indication of which species made up the single schools detected during the day.

As far as the experience gained so far in this area, the only possibility to identify echo traces with any degree of certainty is in areas where fairly pure fish concentrations occur, as in the extreme northern or in the extreme southern areas of the RFS.

PRELIMINARY OBSERVATIONS

In its first year of survey, the RFS has covered the area of reference fairly thoroughly and the principle regions of pelagic fish abundance are now charted. Because of the size of the area covered, much time was spent steaming through unproductive areas. In 1970 effort will be limited to areas where the best fish concentrations were found, principally north of Dakar.

The full potential of the acoustic equipment has not so far been realised but much useful information on fish behaviour has been obtained with acoustic records combined with fishing.

The echo integrator was only installed at the end of 1969 and therefore it has not yielded much information so far. The principal difficulty in obtaining meaningful counts of single echoes is that the particular conditions necessary, namely that the fish be scattered and that they belong to one species and/or size range whose target strength (TS) is known, do not seem to occur very often. Preliminary target strength measurements have been made by reading the peak deflection (oscilloscope v/cm × observed deflection) and relating this to the calibration curve of the echo sounder. Values suggest a TS for *Sardinella* in the 20 to 30 cm (8 to 12 in) length range of −40dB. This type of work depends, however, on using recently calibrated equipment and on having clean transducer surfaces. The extent of fouling by marine organisms in West Africa is high and transducers must be cleaned at least every three months. Even then the effect of fouling at the end of this period has a significant effect on the performance of the equipment.

The mixture of species in scattering layers at night poses the problem of relating a certain type of echogram trace to a particular species. The very rapid change in the behaviour of *Sardinella* at dusk, resulting in a transition from schooling to scattering, combined with the simultaneous upward migration of demersal forms, results in a rather complicated picture. The difficulties of obtaining target strength estimates and of integrating single fish echoes of any particular species therefore remain considerable.

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Applying a Digital Computer Simulation to Evaluating Echo Sounder Design and Performance

J. B. Suomala, Jr.

L'application d'une simulation par ordinateur digital comme aide a l'evaluation de la conception et des performances des sondeurs ultra-sonores

Une simulation par ordinatuer digital a été utilisée pour fournir des informations à ceux qui utilisent et conçoivent les sondeurs ultra-sonores, afin d'illustrer la corrélation des principaux facteurs qui influencent d'une manière déterminante la détection fructueuse du poisson au moyen d'echo-sondeurs acoustiques. Les effets des mouvements du navire, des bruits, de la réverbération, de la grandeuer et de la répartition de la cible sur la zone de détection peuvent être mis sous forme de modèle pour un écho-sondeur donné. Des graphiques d'échogrammes engendrés par l'ordinateur en vue d'une estimation visuelle des effets variés ainsi que d'autres données graphiques ou chiffrées ont été produits par le programme. Une simulation caractéristique d'un écho-sondeur dans un milieu contenant des poissons est décrite, et une évaluation de la capacité du sondeur à fournir des informations pour la détection, la localisation et l'appréciation de la densité des poissons est commentée.

La aplicación de una simulación con ordenador digital para ayudar en la evaluación del diseno y en el funcionamiento de las ecosondas

Se efectuó una simulación con ordenadora digital con objeto de facilitar información a los usuarios y diseñadores de ecosondas para localizar peces, e illustrar la relación de algunos de los principales factores que influyen grandemente en la afortunada localización de peces con ecosondas acústicas. Se puede hacer un modelo de los efectos de los movimientos de los barcos, el ruido, la vibración, el tamaño y distribución del blanco en la zona de localización de una ecosonda específica. La ordenadora produjo planes de ecogramas para la evaluación visual de varios efectos, así como otras enumeraciones gráficas y tabulares del programa. Se describe una tipica simulación ecosonda-ambiente de los peces y se examina una evaluación de la capacidad del sondeador de facilitar información para localizar el cardumen y determinar su densidad.

ACOUSTIC means for fish location and abundance estimation are a complex dynamic combination of electronics, mechanics, acoustics, and biological elements. It is difficult to assess the capability of an echo sounder to display useful information during operations at sea. Also, there may be a tendency for the user of an echo sounder to anticipate more from the instrument than it can provide, if the complexity of the situation is not recognized. Generally, echo sounders, and their associated displays, are excellent fish target detectors, but their capability as fish locators and counters over a range of operating conditions remains to be proven.

The most widely used type of acoustic equipment is the normal or pulsed echo sounder. In this equipment the reference axis of the acoustic energy propagated from a transducer is presumed to be nominally vertical. The uses of, the various forms of these sounders, and associated displays is well documented.

In developing the primary guidance and navigation equipment used aboard the Apollo Command Module and Lunar Module, the technique of systems simulation was used extensively, at the C.S. Draper Laboratory at MIT. Systems simulations were used to examine and predict the behaviour of the guidance and navigation system in the environment of a space flight mission.

The work done to date has been primarily directed toward the examination of the acoustic geometry peculiar to fish detection using pulsed echo sounders. Some work has been done in the area of echo signal conditioning, processing and displays, but this has been considered to be of secondary importance until the environment between the working face of the transducer and the target(s) can be defined with sufficient accuracy to suggest possible variations to existing equipment. The echo sounders that may be simulated are typical of the types that are found aboard many operational fishing and fishery survey vessels.

GENERAL DESCRIPTION OF SIMULATION PROGRAM

It is not intended here to detail the mathematical manipulations embodied in the computer program. Rather, the computations will be described in words as they relate to a particular part of the simulation.

Figure 1 is a diagram of the basic geometrical relationships included in the simulation. This diagram defines the conditions which exist when detecting fish with an echo sounder and the effects of the sea surface and bottom are ignored.

The yaw motion of the transducer and fish motion is not modelled in this version of the simulation. Also not included, is the effect of transducer displacement due to vessel roll and pitch. This displacement is due to the fact that the roll and pitch axes of the vessel are not near the working face of a hull-mounted transducer. The effect of this displacement is not expected to be significant, but remains to be verified.

Fish target array—(program input)

The program establishes a fish target array located explicitly or randomly with respect to the coordinate reference frame (fig 1). The random location may be

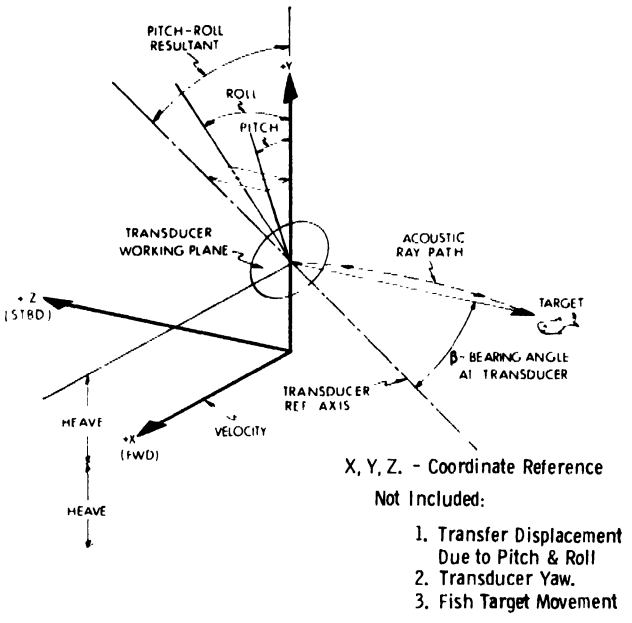

Fig 1. Geometry of simulation

either rectangular or normal (Gaussian) distributions in any permutation relative to the reference frame axes. (Normal along X, rectangular along Y, normal along Z, etc.) A typical target array of 50 fish is illustrated in fig 2. This figure is generated by a plotting routine in the simulation program.

A number of lively discussions with fishery biologists have ensued in the course of time concerning this part of the environment and the explicit or random choice of the fish target array appears to be satisfactory, given that specific information concerning fish distribution other than in high density schools is not likely to be available for some time.

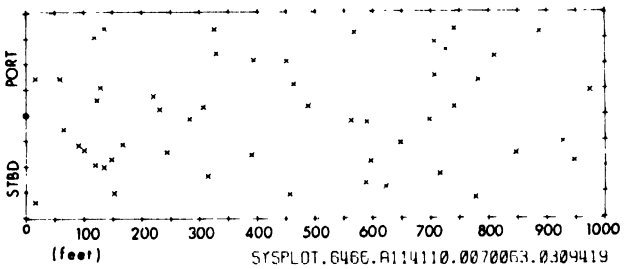

Fig 2. Plan view of fish target array, depth 140–340 ft. (43–104 m)

The target strength (Haslett, 1962) of each fish is assigned explicitly or varying within limits according to a random number series. In the present simulation the fish targets are assumed to have a target strength referenced to an acoustically perfect 2 m radius sphere. By varying the target strength of the fish targets from say, −25 to −40 db, a fish size variation, or a uniform fish size at a varying bearing or aspect angle may be modelled.

Transducer motion—(program input)

The echo sounder transducer is moved with respect to the coordinate reference. The movement of the transducer is the result of velocity, pitch, roll and heave.

The motion used in some of the simulations is the result of monitoring vessel motion with instruments which measure rate of angular change (rate gyroscopes) and linear acceleration (accelerometers). (Toth and Vachon, 1968.)

An analysis of some of the data obtained with these instruments showed that the pitch and roll angular rates at the working face of a typical hull-mounted transducer combined to give a pitch-roll resultant angle versus time shown in fig 3. The pitch-roll resultant angle is the angle between the Y coordinate reference axis of the transducer. (See fig 1).

Figure 4 is the path traced by the transducer reference axis on a plane parallel to the sea surface at a depth of 240 ft (79 m).

The motion of a hull-mounted transducer combined with the sounding rate of the echo sounder creates considerable difficulty for an observer to evaluate a recorder or scope display for useful information, other than the presence of targets.

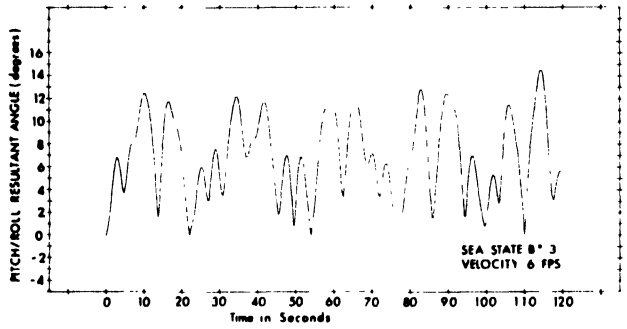

Fig 3. Pitch/roll resultant angle vs time

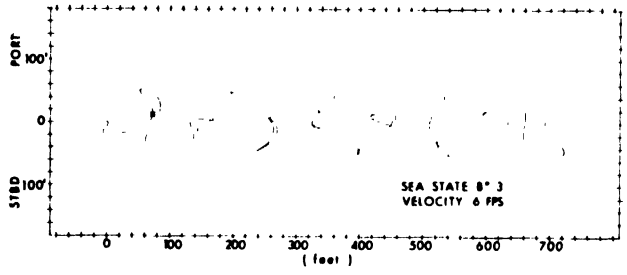

Fig 4. Path of acoustic reference axis on a plane parallel to sea surface at depth of 240 ft. (73 m)

Transducer directivity pattern—(program input)

The characteristics of the transducer are vital to the operational usefulness of an echo sounder. (Urick, 1967; Horton, 1957.) The directivity pattern or overall directional response along with other factors determines the zone of detection of an echo sounder (Haslett, 1961). The zone of detection should not be confused with the half power beamwidth, the conventional specification for acoustical transducers.

The concept of beamwidth is misleading because the acoustic "beam" is not a cone with well identified boundaries but is a concentration of energy, greatest at the centre with side lobes of lesser intensity.

Figure 5 is an example for transducer two way directivity or loss patterns, according to the equations along the

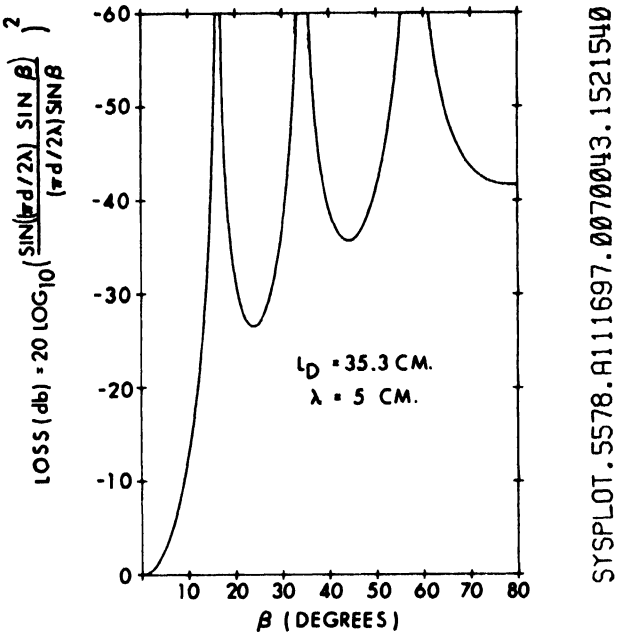

Fig 5. Two way directivity LOSS vs angle. (Diagonal place through reference axis of square or rectangular transducer)

ordinate. These theoretically perfect directivity patterns are included in the simulation and are generated by a plotting routine. The angle β in the figure is the same as the angle β in fig 1.

For each sounding interval the angle β and range (depth) to each fish is computed. Simultaneously, the acoustic path refraction caused by an assumed sea temperature gradient is computed (Horton, 1957). If the acoustic path is greater than the straight line geometrical path, the loss of the acoustic path is used in the computation of the received echo level.

The sources of noise included in the simulation are those caused by the vessel and its movement through the water, the surrounding sea noise and volume reverberation. (Urick, 1967; Horton, 1957.)

Noise caused by the vessel (hydrodynamic, machinery and propeller) is an input parameter to the simulation and is varied as a function of vessel velocity.

Sea noise is an input parameter which is varied according to sea state.

Volume reverberation is also an input parameter and the reverberation level is computed as a function of the range to all fish targets in each sounding interval.

The received echo signal level is computed from all fish targets in each sounding interval.

When more than one fish target is within a range (depth) interval less than one half of the acoustic pulse length the echo signal is a combination of the individual echoes and resolution, or separation, of the individual targets is not feasible with the echo signal processing currently used in normal echo sounders.

The individual target echoes received at the transducer may be in or out of phase, or in any combination, depending upon the range and angle β within the transducer directivity pattern. The received echo levels from individual and multiple fish targets is computed with regard to acoustic pulse length and phase angle.

DESCRIPTION OF PROGRAM OUTPUTS

The program outputs are both tabular listings and graphical plots.

The tabular listing consists of a basic statement. The parameters included in the basic statement are defined by the input variable of the program. Other program variables not in the basic statement require modification of certain sub-routines in the program. The programming effort to modify portions of the program to accommodate changes other than the input variables is minimal.

The basic statement is followed by a listing of the specified fish target array and fish target strength. Next is a listing of the received echo levels from each target in each sounding interval and also a listing which indicates the received echo level from single or multiple targets, phase corrected, and voltages at output of the transducer, the receiver amplifier and at the stylus of a typical wet paper recorder.

Some of the graphical plots included as outputs of the program are illustrated in figs 2 to 5 and 6 to 9.

Also included as an output is a simulated echogram plot. The echogram plots are a graphic display of "echo" which are also printed. All echo signals above a specified minimum recorded signal level are plotted as a function of range (depth). Typical echogram plots are described and illustrated in the following section of this paper.

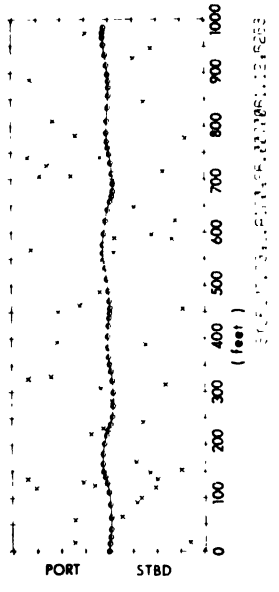

Fig 6.

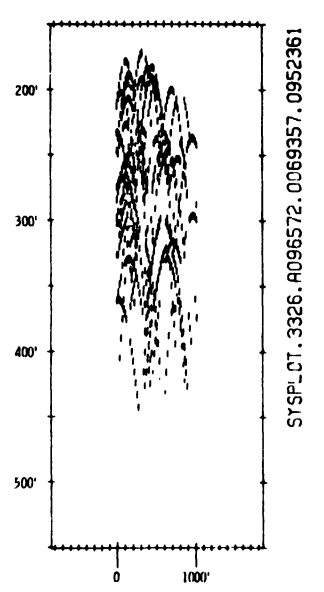

Fig 7.

Fig 6. Plan view of fish target array, depth 140–340 ft. (43–104 m) and data of reference axis of transducer at 240 ft. (73 m)

Fig 7. Echogram plot, SL = 113 dB, T = 0.001 sec (noise only)

TYPICAL SIMULATION DESCRIBED

The initial conditions are specified for a selected simulation to examine the capability of a typical echo sounder to display information so that the following may be done. First, verify the presence of probable fish targets. Second, estimate the probable fish density or number; Third, estimate the towing depth of the net for the maximum capture rate.

The environment listed in Table 1, Initial Conditions, is applicable to the following discussion. The following assumptions are given:

(1) The transducer is assumed to be mounted in a towed body, which is deployed over the vessel side and is connected to a cable of sufficient length in order to minimize the effects of vessel pitch, roll and heave and vessel generated noises.
(2) The transducer is assumed to have a maximum pitch and roll angle of $\pm 3°$ from the vertical.

A plan view of the fish target array and path of the acoustic reference axis of the transducer at a depth of 240 ft (73 m) is illustrated in fig 6. The small circles on the reference axis path indicate the sounding interval.

Readers familiar with "true" echograms will immediately note that the computer generated echogram plots do not have the "feel" of a true echogram. This is the result of the digital form of the simulation. The program generates an echo trace if it is above a specified minimum echo signal level and does not indicate the amplitude (voltage) variations in the received signals which occur under actual conditions at sea. For this reason some of the isolated echo traces illustrated in the following figures would in all probability not be noted in a true echogram because of recorder variable dynamic range limitations.

When referring to the simulated echogram plots the reader should keep in mind the following. First, the traces are not intensity modulated and many of the isolated traces would not be easily identified in a true echogram. Second, the traces are intentionally wider spaced than normal. (This is done for verification purposes with the listing of the simulation program.) Third, the copying process degrades the fidelity of the original. Fourth, all echogram plots are of the initial conditions, listed in Table 1, except as noted. Many of the isolated traces are the result of fish target signal acquisition in the minor lobes of the transducer directivity pattern.

Figure 7 is the result of a sounder source level=113 db//1 μbar, a pulse time duration of 0.001 sec and illustrates the effect of noise only. (Minimum recorded signal—25 db.)

Figure 8 is the result of the identical conditions in fig 7 and illustrates the effect of both noise and reverberation.

These examples for simulated echogram plots could, of course, be extended to show for instance the influence of reduced source level, decreased pulse time interval and the respective interactions with reverberation and noise.

Keeping in mind the three requirements that were mentioned earlier, it would appear that all echogram plots could be used to verify the presence of fish targets.

The second requirement, estimation of the probable number of fish or density cannot, with any degree of confidence, be accomplished.

The third requirement, estimation of towing depth, would be a minimum of 170 ft (52 m) since no fish targets appear shallower, but any depth estimate to maximize capture rate is not practical.

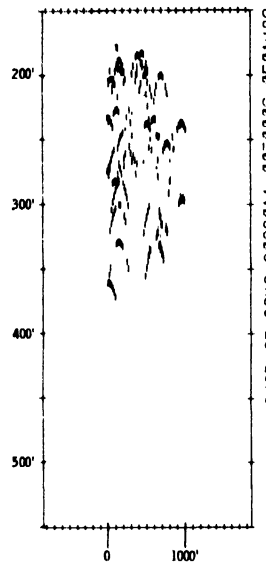

Fig 8.

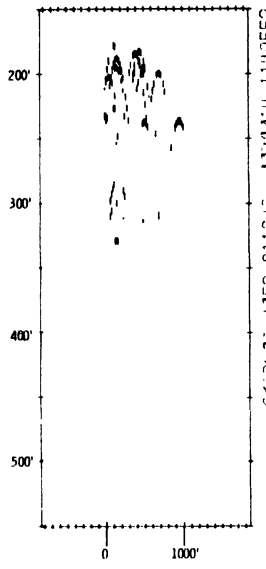

Fig 9.

Fig 8. Echogram plot, SL = 113 dB, T = 0.001 sec (noise and reverberation)

Fig 9. Echogram plot, SL = 113 dB, T = 0.001 sec (noise and reverberation)

EVALUATION OF AN ECHO SOUNDER

The following is an example of an evaluation of the echo sounder in a specified environment.

The environment specified in Table 1 was selected to illustrate a fish distribution which, if sampled with a 1600 mesh midwater trawl net, would have a minimum probable capture rate of 3000 lb. (1360 kg) per hour of towing time.

The rationale supporting this particular simulation is based upon the premise that profitable midwater trawl fishing can be sustained, if the minimum capture rate occurs no more than 60 per cent of the time the trawl net is fishing. (Gardner, 1968).

Assume that the echo sounder operator knew from other observations, say, the lower sea temperature limit of the particular fish species sought and that the actual sea temperature at 340 ft (104 m) was this lower limit. He could then vary the recorder gain until no echo traces appeared at a depth greater than 340 ft (110 m).

Figure 9 illustrates the effect, on fig 8, of raising the minimum recorded signal (lowering the recorder gain) until no echo traces appeared at a depth greater than 340 ft (104 m).

An examination of this figure might lead some observers to attempt a subjective estimate of fish number or density, based upon prior experience, but correlation with the true environment is tenuous.

Assume that the echo sounder operator had no knowledge of the depth limit of the species sought, but varied the recorder gain until the echogram appeared "right", based upon his previous experience, and by accident fig 9 was the result.

The estimation of a net headrope minimum depth of 170 ft (52 m) would be again made and a maximum depth of the net footrope would be about 250 ft (76 m).

If the recorder gain was further reduced until only the strongest echo traces were visible the estimation of net depth would be from 170 ft (52 m) to 220 ft (67 m) and an estimate of the number or density of fish would lead the observer to the probable decision that to set and tow the net was not worth the effort unless other information or knowledge of the environment was to reverse the decision.

The preceding discussion serves to illustrate some important operational limitations and constraints imposed upon the user of a typical echo sounder during midwater trawl net fishing on scattered fish.

Table 1

INITIAL CONDITIONS

Vessel Ground Speed - 10 Kn, Sea State - B^0 3
Transducer Stabilized - $\pm 3^0$ from vertical - Towed
Sounder Transmitting Frequency - 30 KH_z
Transducer Diameter - 5 λ
Transducer Directivity Response = $\frac{2J_1(x)}{(x)}$ (Shaded for optimum side lobe reduction)

Ambient Noise Level - (- 42) db.
Volume Reverberation Scattering Strength - (- 100) db.
SNR (Receiver Output)-(+6.0 db).
Time of Run - 60 seconds.
Number of Fish - 50
Fish Target Strength - (-25) to (-40) db. Random.
Fish Location - Sea Volume 1000' (3048M) along track.
± 180' (55M) cross track.
- 140' (43M) to -340' (104M) depth.
(Rectangular Distribution)
Sounding Rate - 1 per second.
Receiver Sensitivity - (-55 db)
Receiver Amplifier Dynamic Range - 125 db
Transducer Receiving Sensitivity -(-30 db)
Recorder Dynamic Range - 20 db (3-30 volts)
Sea Temperature Gradient.
0 -65 feet 70^0 (21.1^{0}c)
65 - 365 feet -0.07^0 F (-0.0385^0 c)/ft. (0.305M)

LIMITATIONS OF THE PRESENT SIMULATION

The limitations discussed are primarily due to the amount of effort that has been available to develop the simulation program. The versatility of the simulation seems to be limited only by the amount of time and money available to add more sophisticated techniques.

The following lists the major environmental effects not included in the simulation.

1. Fish targets have no directivity, i.e. they are assumed to have the same target strength at all aspect angles
2. Fish targets do not move
3. Scattering in the presence of closely spaced fish targets
4. Effect of scattering layers
5. Doppler shift
6. Transducer motion on signal to noise and signal to reverberation levels
7. Effects of reflection

The effects mentioned above are considered to be significant when combined.

CONCLUSION

The simulation described can be employed to examine some of the major effects which improve or degrade the operational usefulness of an echo sounder in a specified environment.

By establiishing an environment; target strength, location, noise, reverberation, etc., physical insight into conditions which exist at sea can be gained.

The combination of physical insight into the environment and an intimate working knowledge of the echo sounder sampling the environment can provide a strong background for persons engaged in fishing operations.

The simulation described is considered to be useful for both fishermen and equipment designers, as a first approximation, for the examination and evaluation of the operational usefulness of the normal echo sounder.

In order to increase the validity of the simulation, beyond the first approximation level, a series of carefully planned and executed measurements at sea must be accomplished. (Suomala and Vachon, 1969.)

Further development is required and when completed the program would have, as one of its outputs, the specification of echo sounder system parameters for the most effective fish detection in terms of an anticipated or known environment.

Simulation program language

The simulation is programmed in MAC-360. MAC-360 is an algebraic compiler developed at MIT, C.S. Draper Laboratory, for use in digital computations in fields such as dynamics and control theory. MAC is a programming language, designed to simplify the task of describing the mathematics of space mechanics. It features a three-line format, permitting the use of superfields and subfields while preserving their readability. The use of superfields which define vectors and matrices allows a concise and powerful notation of complicated algebraic expressions.

The simulations described in this paper were performed on an IBM System 360 Model 75 Digital Computer at the Draper Laboratory.

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DISCUSSION

ECHO SOUNDING

Craig (UK) Rapporteur: The papers in this session fall into two groups: technical and engineering aspects. **Tucker** emphasizes among other things the significance of new circuit elements, particularly integrated circuits, and the fact that their use will make possible cheaper, more reliable and more sophisticated equipment. The same opinion is expressed in two other papers and clearly this is something which has developed since the last Gear Congress. Much more complex equipment can be built now because of these circuits.

Hashimoto, Maniwa and **Kato** describe a radio remote-reading echo sounder and suggest such a system will enable better decisions to be made in purse seining and in the operation of fixed fish traps (setnets). This system would also have considerable potential in fisheries research. Although this is not a new idea, I think it is the first report on experiments to be made available. The idea of putting echo sounders on boats, perhaps unmanned radio-controlled vessels, and being able to receive the recordings at a shore centre or on another ship, seems to have quite wide applications well beyond those which have been suggested.

Suomala's paper describes an exercise of some significance for design studies of equipment, which may well also have applications in high level training, bringing about the possibility of looking at hypothetical situations and seeing directly what sort of echo records would be produced in certain situations—a special topic of which we have heard nothing in the past.

Tanaka describes the multi-stylus recorder, which in my own summary paper I have put down as the most notable advance since the last Gear Congress. This technique gives very much more flexible recording, scope for greater accuracy, for multiple records and a large variety of improved presentations, from which both skippers and research could benefit considerably.

The contribution by **Mross** and **Purnhagen** is difficult to summarize, because it reviews many aspects. For manufacturers and technicians it may well be the most important paper we have ever had before a Fishing Gear Congress. In respect of the mechanical design of transducers the authors are not alone in their preference for mechanical biased PZT (lead-zirkonate-titanate) to any other construction, as it is a much-favoured method of producing transducers. They also discuss the increased scope given to designers by integrated circuits, with special emphasis on delay systems. Perhaps the authors could make it clear whether they are delaying an analog signal or a digital signal. There is a considerable difference between the two and delaying analog signals whilst preserving their amplitude is more complicated. They then consider the

design of signal amplifiers and report on improvements in voltage discrimination circuitry and improved steady signal display for cathode ray tubes. The alternative approach to scale expansion recorders suggested is rather interesting in that it shows how the performance of multi-stylus recording can be achieved without having a multi-stylus arrangement. The design philosophy given at the end is worthy of study by all concerned with system design.

Pearce and **Philpott** describe a system in which the transmit beam of an echo sounder is stabilized against roll of the ship by electronic means. Initial results with this sytem have shown it to be helpful and effective, but not quite to the extent hoped for. **Miyajima** continues this theme, reviewing both mechanical and electronic methods of stabilizing sonar beams, but without giving a great deal of detail. This is more a reference paper which will allow technical experts to follow up what is being done in Japan.

Hearn describes a rather unusual project which is worthy of close study. In order to predict trawl catches, a fish echo counter is recalibrated by taking note of what the last catch gave.

Nishimura reviews many aspects of fish detection in Japan such as the choice of frequency for echo sounding and fish counting systems including a method of pattern analysis to identify species. Unfortunately this method is not explained. The technique of wireless netsonde and the introduction of multi-stylus recording in Japan are emphasized. A rather surprising conclusion is the prediction of a slow-down in acoustic engineering in Japan, at least so far as fisheries are concerned.

Kudryavtsev gives specifications of sounders used in the USSR and deals also with problems of sounding through ice and with experiments in detection of fish down to more than 1,000 m in depth. This is a wide ranging paper, much of which falls outside the scope of the present agenda item.

In my own paper I have endeavoured to trace advances since the first Gear Congress in 1957—which are less than might have been expected and hoped for, due to the fragmentation of development into small widely separated groups in many countries. An example is the multi-stylus echo sounder and the alternatives to it. There can be no end to minor improvements and variations of displays, but fundamentally we have to get acoustic information about fish. With good resolution and sufficient knowledge of what the signal amplitudes mean, the right thing to do is to move towards a computerized system which can tell, either by displaying numbers or by making larger calculations, when to shoot the net. The fishermen and the fisheries biologist should specify what they need to make their decisions and on this basis the optimum display should be devised. This approach is apparent in the philosophy of **Mross** and **Purnhagen** and one finds something of it in the paper by **Hearn** who is trying to produce a simple numerical output on which decisions can be made. There are obviously many intermediate stages on the route to this goal but main emphasis should be on trying to analyse and reach conclusions from fish echo signals rather than, for instance, trying to find other ways to play back the signals many times over. This is not a criticism; we all understand why a steady CRT display is useful. But perhaps it is not the most useful thing that we can do with acoustic information. I mention the need to use and understand the meaning of signal amplitude and the significance of time varied gain (TVG). Manufacture has now reached the stage where one can begin to expect acoustic results to be quantitative.

Mross (Germany): During the early sixties it became obvious that the old electro-mechanical and vacuum tube techniques presented a serious handicap to substantial progress in fish detection by echo sounding. This realization has grown with the increased need of the skipper to get more comparable and reproducible quantitative information in order to make better decisions with growing competition on the fishing grounds. So the basic principle for new developments as far as we are concerned is the use of the most modern electronic and hydroacoustic technology to pave the way for tomorrow's progress of performance and information. Accordingly, a completely new echo sounding electronic circuitry has been developed. Apart from the use of high performance solid state components, integrated circuitry and digital technology was introduced. Magnetostrictive transducer systems had to be replaced by a commercial adaptation of the lead zirkonate titanate ceramic transducer technology used in most advanced navy systems.

We are aware of the fact that new technology as well as changes in fishing operations must necessarily be accompanied by a further development of established concepts of servicing. The extensive use of the principle of standardized plug-in modules was therefore extended even to whole mechanical assemblies.

The digital Steady Picture Storage unit described depends on Large-Scale Integrated Circuits (LSI). It has a volume of 8.5 litres and power consumption of 40 W. If the same unit had been built in discrete transistorized or vacuum tube technology we would need about 25,000 transistors or 12,000 tubes, which would result in a volume of about 200 litres or 5,000 litres respectively. In the latter case the power consumption of the tube heating alone would amount to 24 kW.

The multi-stylus recording system, undoubtedly is an interesting development and causes wide interest. For reasons of serious limitations in definition, however, I am sure this system does not have a promising future. Computer technology with its high capacity shift register memories on LSI chips shows us a new way, which incorporates all the functional advantages of the multi-stylus system, but does not have its limitations.

Purnhagen (Germany): Let me give a brief explanation of how analog echo information can be stored digitally. After the echo signal has been rectified, the resulting analog DC-voltage is measured at discrete time intervals (time steps), the duration of which are such that no significant amplitude information is lost. The voltage is measured by an analog-digital converter, which consists of a staircase generator, the output of which is compared with the analog echo voltage. At the beginning of each time step the staircase starts at zero volts and rises in small steps (amplitude steps) up to its maximum value. The amplitude steps are also chosen as small as necessary to preserve full information. The number of steps necessary to get the same voltage as the analog voltage is counted, (e.g. $LOL - 1.2^2 + 0.2^1 + 1.2^0 - 5$) and stored in the shift register. The number of parallel shift registers, each storing a row of "yes" or "no" information, depends on the number of amplitude steps necessary, e.g. with six shift registers in parallel an amplitude resolution of $2^6 = 64$ amplitude steps is achieved.

The digital information stored in the shift registers is reconverted by a digital-analog converter.

Ludwig (Germany): Agreed with **Mross** and **Purnhagen** that the multi-stylus system may not present the most useful approach for the future. He felt that in view of the occasional trouble experienced with a single stylus one might expect appropriate multiplication of such difficulty with many styli. Another apparent difficulty with multi-stylus recorders is their restriction to dry recording paper only.

McNeely (USA): Regarding **Hearn's** paper, considered it more important to quantify a fish resource before a catch is made rather than after and wondered how the equipment described by **Hearn** could extrapolate the results of searching at 10 knots to trawling at lower speed.

Grönningsaeter (Norway): Showing slides of a clear resolution photograph of a black halibut taken at 1,100 m depth off the west coast of Norway, proved that deep penetration by photography was possible at a range from the target of about 15 m. To use such a fish finding system effectively would require precision navigation with accuracy of also 15 m. This is possible with the Decca Navigator system, particularly if combined with a Track Plotter.

Gerhardsen (Norway): Contrary to the impression created by some participants and some of the papers, he assured the Conference that micro-component development and the use of computer techniques is not new to manufacturers of echo sounding equipment. He also considered the multi-stylus recorder a useful device under certain conditions and agreed that minor improvement in display may not be what we are really after. An echo sounder should be more than something showing a fish and should be capable of indicating quantity of fish.

Ludwig (Germany): Referring to the sonar equation he felt that target strength should not be considered a single parameter but more as a sum of parameters and until all these were known and defined it should be difficult to obtain quantitative indications. While the development of echo sounders using computer techniques will no doubt continue, he felt that this is useful only in connection with more symphatic displays, which will allow the skipper to make the necessary decisions after one look at the equipment, instead of having to consider a number if digital outputs.

Craig (UK) Agreed with **Ludwig's** remarks on the complexity of target strength.

Mross (Germany): Although echo counting will be discussed later on, he stressed the close relationship between the echo sounder, computer, logics and counting devices, the performance of which depends on the quality of the information and this again on the definition of the basic sounding system. Better definition of sounding systems will make counting problems easier, dut there are still general problems with regard to fish schools as compared to single fish.

Goodlad (Canada): New developments in sounding equipment tend towards increasing complexity. Manufacturers should keep in mind that users of this equipment are not acoustic experts and that whether the internal parts of the equipment become more sophisticated or not the display and controls should be kept relatively simple.

Drever (UK): As a professional fisherman I couldn't agree more with **Goodlad's** remark. Equipment in general is getting more complicated all the time and there is a definite need for simplification. This applies for instance to the Kelvin Hughes Humber gear which is an excellent aid for fish detection and also for estimating the catch before you haul. In this respect I strongly disagree with **Hearn's** remark that his 50 per cent hits are an improvement on the skippers estimate.

Mross (Germany): I think the idea of the telesounder eventually being suitable for the search of fishing grounds by unmanned vessels from which the records are communicated to a shore-based evaluation centre is valid, but I suspect costs would be so high that international cooperation or backing would be needed for the development and operation of such systems.

Olsen (FAO): Before discussing the use of unmanned vessels questions of how to operate them economically, technically and legally would have to be solved.

Laevastu (USA): The cost of a large telesounding system would be too high to make it profitable for fisheries. Smaller recoverable systems in, say, dinghies might be useful and possible in some fisheries, but, I doubt that the advantages of even such a limited system would justify the cost.

Mross (Germany): In view of the fast rate of technical development I am not as pessimistic as **Laevastu** and I hope that progress will be reported at the next Fishing Gear Conference.

Hjul (UK): I would like to mention the problem of echo sounders for developing countries. I think there is an important task for FAO in this field. I should like to know what will be done to ensure that simple, low-cost echo sounders will be available for fishermen in such countries. Can the manuturers of echo sounders give an answer to this question?

Ludwig (Germany): Small, cheap and reliable echo sounders are already available, the development of which was made possible by the technique of integrated circuits. "Cheap" should be understood here as better performance and more reliability for the same price as before. Manufacturers are well aware of the need to produce small echo sounders for small fishing vessels of developing countries.

Kristjonsson (FAO): I think the discussion so far may be misleading with regard to progress in echo sounding. There have been very significant developments for commercial fisheries in recent years which were discussed only as likely future developments at the last Gear Congress. In Japan, for instance, much use is now made of scale expansion, which can not only be locked to the sea bottom but is also moveable between the zero line and the bottom. Several degrees of scale expansion segments from 5 fm to 50 fm are available, sometimes displayed on the same paper as the echogram of the total depth from surface to bottom. The lower part of the paper is then reserved for the scale expansion display. This is said to be very useful in many fisheries, not only bottom and midwater trawling but also in tuna longlining, and of course purse seining. Another equipment commonly found on Japanese vessels today is the multi-stylus recording which is being used predominantly by two firms in their big echo sounders. I think some of the speakers have been too pessimistic in their comments on multi-stylus recording. FAO has been using such an echo sounder in one of the field projects exloring the South China Sea which has not been exploited for commercial fishing up to now. After this unit was installed in the vessel much more precise information was obtained about fish not only on the bottom but also in midwater. In one year of operation we have found the system very reliable despite its reputation of being difficult to maintain. Time varied gain is available in some European sounders now, and dual or multi-fequency sounders are commonly used in all Japanese fisheries. All Japanese tuna longliners have dual-frequency echo sounders, normally 28 to 200 kHz which they use for determining the mixed layer depth and deep scattering layer. Because the tuna normally feed or concentrate near the mixing layer and near the deep scattering layer, dual frequency echo sounders are used now more as a guide than the bathythermographs relied on earlier for choosing the depth at which to set the lines. The biggest purse seine fishery in Japan is for mackerel and horse mackerel with catches of about one million tons per year. Of the 1,500 purse seiners, the more modern ones at least in the south of Japan, are equipped with dual-frequency sounders for finding schools during daylight —low frequency sounding being used for this purpose. In night fishing by light attraction, high-frequency sounding is used to judge the density and size of schools. Finally, narrow beam echo sounders with stabilized beams are discussed, this being one of the big hopes for finding fish very close to the bottom in the future.

Mross (Germany): Agreed that high frequency echo sounders would provide improved echo definition. This is due to the

narrower beaming and the shorter pulse lengths possible with high frequencies. He felt, however, that the development of improved transducers will gradually make these advantages available in lower frequencies, and thus extend their utilization to greater depths than the strong attenuation of high frequencies allows so far. He believed that high frequencies will always be more efficient for the echo recording of temperature layers.

Nomura (Japan): In Japanese trawling 50 kHz is used for long range fish detection and 200 kHz to identify targets. Such dual frequency combination echo sounders are commonly used by the Japanese trawler fleet.

Shibata (Japan): Dual frequency echo sounders operating at 50 and 200 kHz are used in shrimp trawling in the Yellow Sea during the winter in 40–140 m depth. Shrimp traces can easily be distinguished from fish traces, by comparing the two echograms of 50 kHz and 200 kHz, since the echo from shrimp (*Penaeus orientalis*) at 200 kHz have a particular amplitude. In Suruga Bay shrimp trawlers also use 200 kHz for detecting layers of shrimp (*Sergestridae*), while plankton layers (Salpa?) show a characteristic echo amplitude on 14 kHz sounders. The latter is also true of the deep scattering layers in the Pacific Ocean.

Tucker (UK): For low frequency echo sounders the solution may lie in the use of non-linear acoustics. A highly-directive beam may be produced from quite small transducers by causing the interaction of two high frequency waves to produce a directive signal at the difference-frequency. The principle has been well proved, and a sea-going echo sounder using it is nearing completion and will shortly undergo trials.

Nakken (Norway): Agreed with **Craig** about the usefulness of TVG in commercial fish finding echo sounders which, together with CRT, will help the fishermen to better estimate the size of fish or fish schools. Furthermore, fishermen often use a rather low amplification to ensure that fish concentrations they detect are worth catching. Without TVG there is the possibility of missing deep scattering layers which may be catchable later in the day or night.

Yuen (USA): If using a TVG, do you not lose some flexibility? If the target is not strong enough to be detectable at a maximum range it cannot be detected at a closer range because of the TVG.

Craig (UK): Yes. If the gain set with TVG is not enough you will not detect certain weaker targets at any depth. Obviously TVG is intended to provide optimum equal gain from the surface down to some maximum depth. The fact that smaller or weaker targets closer to the transducer are not shown is not a drawback but on the contrary is the main feature of TVG.

I will briefly explain what is being done in the UK on quantitative acoustic methods. First, there is a cooperative investigation of fish target strengths involving several institutions in the UK. Then there are two Scottish programmes in progress at Aberdeen. We have made a counting echo sounder working at 400 kHz, with a very narrow acoustic beam and good range resolution. A towed body is used to stabilize the transducers and the output is computer-processed to give numbers of fish, and their target strength, for each depth. Finally, we are pursuing the statistics of fish distribution. Without such studies it would not be possible to furnish confidence limits for any population estimates.

Midttun (Norway): The echo integrator presently used in Norway is a commercial unit produced in Norway. Before integrating the received echo, voltages are squared in such a way that they represent target strength. Useful application is so far limited to favourable conditions of fish distribution. A more sophisticated method of this kind using a computer can be inspected on the new Norwegian Research Vessel *G. O. Sars* which is in the harbour.

Alverson (USA): Explained briefly that there are two areas of investigation involving echo counting presently going on in the USA. The research vessel *Oregon* has a multi channel device with computer storage and sorting. In the Pacific North West, the Bureau of Commercial Fisheries has run quantitative echo surveys jointly with the USSR. In a comparison of results from a survey off the west coast of the USA good results with regard to identification of schools and their geographic distribution features were obtained. Estimates of stock size were not as close as might be desired.

Klima (USA): The research vessel *Oregon II* is equipped to process echo signals in real time with a small computer. This system identifies fish schools and quantifies the school. The vessel has just returned from a preliminary cruise on quantifying fish schools with the new system.

Davies (FAO/Peru): In Peru we are using the same equipment as described by **Raitt, Losse** and **Schmidt** and have obtained very similar results. The basic problems encountered have been target identification, and mixed fish and plankton layers.

Olsen (FAO) Rapporteur: There are several more FAO projects carrying out quantitative echo surveys with equipment similar to that described by **Raitt, Losse** and **Schmidt.** As a by-product these projects have developed a standard methodology, which is actually a combination of the methods used by many other laboratories and it is hoped that this will result in a systematic text book for echo surveys.

Yuen (USA): Commented on a pattern recognition of tunas as used by the Japanese. On the sounder a tuna creates an arrowhead shaped record. This pattern is fed into the computer and each echo is matched against it. If the echo shape does not match the pattern it is not counted as tuna. He is not convinced that this system is without ambiguity.

Midttun (Norway): In Norway identification of targets is attempted by sampling single echos through a computer at the fast rate of 50 kHz.

Mross (Germany): Fishing skippers can recognize from experience in certain fisheries some fish species on the echogram and/or CRT through their specific behaviour or schooling which give certain characteristic display patterns.

Drever (UK): On the CRT display experienced skippers can tell the difference between cod and redfish.

Margetts (UK): Felt that there has not been sufficient concerted efforts on the part of acoustic engineers in the identification of fish with sounding equipment. There is a real need to identify fish species located by echo sounders. The tendency has been for the acoustics engineer to leave this to the biologist and for the biologist to want the acoustics engineer to do it for him. It is easy to suppose that echoes can be identified by catching the targets, but fishing gear is very selective and catches do not necessarily represent what is giving the echoes. Even when trawls, lines, cameras, television and plankton nets have all been used on one echo trace their combined results have sometimes been confusing, so any one method of identification would have been most misleading. It is important that the problem of echo identification be kept to the forefront and that every opportunity be taken by technologists and fisheries biologists to do what they can to solve it, whether by acoustics and electronics or by better catching means, and that ideas towards these ends be made known.

Review of Present Status of Sonar Equipment and its Application

Gudmund Vestne

Etude de la situation actuelle de l'equipement sonar et de son application

Pour choisir le sonar qui convient et pour lui donner l'application optimale à la pêche, il est indispensable d'en connaître las données physiques et techniques fondamentales. Pour la pêche, c'est-à-dire essentiellement pour le sennage et le chalutage, on utilise couramment le type de sonar "projecteur" muni d'un transducteur orientable horizontalement, voire verticalement. D'autres types de sonar sont actuellement surtout utilisés pour la recherche, tels que le sonar à balayage de secteur électronique le sonar à modultation de fréquence avec transmission continue, le sonar pour trait de profondeur variable et le sonar à orientation latérale, mais les principes sur lesquels repose cet équipement pourraient bien être appliqués à la pêche dans l'avenir. Bien que le sonar soit surtout utilisé pour la détection des bancs de poissons pélagiques et des bancs de surface, il peut également être appliqué à des bancs de fond pourvu qu'ils soient suffisamment importants, ainsi qu'à la détection des obstacles. Le sonar, déjà couramment utilisé pour la pêche à la senne coulissante, s'emploie maintenant de plus en plus également pour le chalutage, notamment avec le chalut flottant. On dispose désormais d'une vaste gamme d'appareils qui suffisent pratiquement à satisfaire tous les besoins de la pêche. L'innovation récente est l'adaptation du sonar à l'équipement netsonde. L'application efficace du sonar pour le repérage du poisson, de même que pendant la phase de capture, nécessite bien entendu une expérience considérable. Le document donne à titre d'orientation, des exemples de situations de pêche caractéristiques. Le sonar actuel "projecteur" présente certaines faiblesses en ce qui concerne l'ampleur et la couverture de la zone de détection, l'identification des objectifs, l'estimation de l'abondance du poisson, l'indication de ses déplacements et de son déploiement pour en faciliter l'évaluation notamment pendant la phase de capture, tous problèmes dont la solution nécessite des efforts soutenus.

El equipo actual de sonar y su aplicación

Para la buena elección y aplicación en la pesca de un aparato de sonar es esencia tener un conocimiento básico de sus fundamentos físicos y técnicos. Para la pesca, principalmente la de cerco y de arrastre, el sonar màs comúnmente empleado es el de "seguimiento automático" con transductor direccional y, a veces, inclinable. Otros tipos de sonar, tales como el de exploración de sector electrónica, el de transmisión continua con frecuencia modulada, el remolcado a profundidades variables y el de escucha lateral, se emplean sobre todo para la investigación, pero es muy posible en el futuro alguno de ellos se emplee también a la pesca. Aunque el sonar se utiliza predominantemente para localizar los cardúmenes de peces que nadan en la superficie o entre dos aguas, puede emplearse también para la localización de bancos de peces de fondo suficientemente grandes y para la detección de obstáculos. El uso del sonar, que ya es normal en la pesca con artes de cerco, es cada día más frecuente en la pesca al arratre, en particular el pelágico. Actualmente existe una vasta gama de tipos de sonar, que responden prácticamente a todas las necesidades de la pesca. La última novedad es la adición del sonar al equipo de sondeo acústico montado en la red. Para emplear eficazmente el sonar en la localización de los peces y durante la fase de captura se requiere considerable experiencia. Como orientación, se dan algunos ejemplos de situaciones típicas de pesca. El sonar de seguimiento automático presenta algunas deficiencias por lo que se refiere a la extensión del campo y a la cobertura del mismo, la identificación de los blancos, la evaluación de la abundancia de peces, la indicación de sus movimientos y la representación en forma que permita una fácil evaluación, sobre todo durante la fase de captura cuya solución exige estudios continuos.

THE number of sonars used in fishing fleets is increasing rapidly. From being a fish detection instrument in research vessels, it has become an indispensable tool for thousands of fishing skippers on purse seiners and trawlers throughout the world.

SONAR is an acronym for SOund NAvigation and Ranging. As the name indicates, sound waves are used to find both the direction of and the distance to a target in the sea.

Some of the basic physical principles of sonar must be considered in order to provide the necessary background when the status of sonar should be reviewed.

What should be considered are:

Generation of a sound pulse
Propogation of sound in water
Reflection of sound from a target
Reception of an echo signal in presence of background noise

Besides those factors there are others that influence the use of sonar. These are: (a) Refraction of the sound beam and (b) Pitching and rolling of the vessel.

Normally the transmitted sound pulse should be as powerful as possible. This is achieved by means of high transmitting power, high transducer efficiency and concentrated, narrow beam. Large dimensions of the transducer surface give a narrow sound beam. The limit for the strength of the pulse is set by the water and occurs when cavitation takes place on the transducer surface.

CHARACTERISTICS OF SOUND

When sound passes through water, the sound intensity decreases. This decrease is due to both geometrical spreading and energy absorption. The spreading is independent of frequency while the absorption is highly frequency dependent.

The maximum range capability of a sonar equipment is mainly governed by working frequency and noise level, and less influenced by other factors such as transmitting power.

When sound strikes an object in the sea, part of the sound will be reflected. The strength of the reflected signal may vary greatly depending on size of the target, its characteristics and on the direction of the incident sound waves.

To detect the signals reflected from a target, the echo level must exceed the background noise level.

The main sources of background noise are the propeller, the engine and the turbulent flow of water along the hull and around the sonar transducer.

It is important to keep noise level from the different sources as low as possible to be able to detect weak echoes at long distances.

Normally sound waves do not spread along a straight path. Due to change in sound velocity with depth, changes in temperature, salinity and hydrostatic pressure, the sound path will be deformed.

Sound travels faster in warm than in cold water, hence the beam tends to bend towards cold water. This fact

highly limits the use of sonar under certain water temperature conditions.

Obviously problems arise when a narrow sound beam is directed towards a distant target with the ship rolling and pitching. To reduce this fundamental shortcoming in a sonar system a wider beam may be used, or the narrow beam may be stabilized against roll and pitch.

SONAR EQUIPMENT

Sonar equipment for fish detection must meet a number of partly conflicting requirements. The complexity and bulk together with the cost must be reasonable while maintaining long term stability with satisfactory fish detection capability. These requirements are met by the searchlight sonar.

The searchlight sonar consists basically of a pulse transmitter, a transducer, a receiver and a means for presenting information. In addition it comprises a hull unit which serves as a platform for the transducer which transmits the sonar pulses into the water and detects the returning echoes from objects in the sea.

The sonar transmitter produces powerful pulses of short duration. Common pulse lengths are from 1 to 30 millisec, the selected pulse length being dependent on the operating conditions. Longer pulse lengths are used for long range operation. Short pulse lengths provide sufficient echo return at short range and also improve range resolution.

The emitted frequency may vary from 10 kHz to 250 kHz depending on type of sonar. The choice of frequency is determined by a number of factors. As a general rule a low emitted frequency provides a long detection range but bulky and costly equipment. Whereas a high emitted frequency provides a better resolution at a reasonable price with less bulky equipment, but at the expense of range.

The sonar receiver amplifies and shapes echo signals picked up by the transducer. To secure intelligible presentation of the echo signals the receiver normally contains various automatic signal processing elements.

Initial suppression ("Main bang suppression") reduces the receiver sensitivity when and immediately after the transmitter pulse is emitted in order to avoid overloading the receiver.

Noise level in the sea is generally very high, and to improve the readability of the echoes a delayed automatic gain control ("AGC") is applied. The bandwidth of the receiver is kept as narrow as possible to keep the noise at a reasonable level, but must be high enough to pass sonar pulses without undue distortion and also allow for the doppler effect.

The sonar transducer is positioned under the bottom of the ship with free sight in all directions. The sound pulse is emitted from the face of the transducer in a narrow beam. Echoes returning from the same direction are transformed in the transducer into electric pulses which are sent to the receiver.

The hull unit serves as a platform for the sonar transducer. It is important that the transducer when in operation, is positioned well below the lowest part of the ship's bottom, primarily to ensure free sight in all directions, but also to ensure that the transducer is operating outside the layer of turbulent and aerated water along the ship's hull. In addition the operator must be able to train and tilt the transducer at will.

The construction must therefore be able to withstand considerable pressure from the sea when cruising, and must preferably be retractable when not in use.

For ships operating at moderate cruising speeds, noise from turbulence around the transducer and protruding parts of the hull unit is tolerable. For higher speeds, however, it is necessary to cover the transducer and its fixtures with a dome. This dome is preferably streamlined, especially if searching speeds above 12 kn are desired. An additional advantage of a streamlined dome is that the risk of ropes and gear getting entangled is avoided. Such streamlined domes, however, invariably require a fairly large hull unit.

The most common form of dome on smaller craft is as a bucket bolted to the transducer shaft, as this type requires a less bulky hull unit with a corresponding saving in hull space.

Training and tilting of the transducer must be remotely controlled from the bridge, where instruments indicate the instantaneous direction of search.

Methods of presentation

The echo information may be presented on a paper recorder, on a cathode ray tube or by sound. Very often sound presentation is used in conjunction with either a paper recorder or a cathode ray tube.

An experienced operator uses the sound to distinguish between echoes from surface waves or from the bottom, and also between reverberation and background noise. Particularly in the automatic searching mode, the loudspeaker is used extensively as sound presentation greatly reduces the strain when searching for fish.

The cathode ray tube is used to some extent, but as velocity of sound in water is very low, a satisfactory picture is obtained only on short range with the standard cathode ray tubes at present available. The paper recorder is universally accepted as a good fish echo indicator. Not only does it provide a clear presentation, but it is also an efficient correlator. An echo may be visible as a tiny marking on the paper just above noise level, and it is difficult to tell whether it is an echo or just noise. If, however, the marking continues to appear in subsequent transmissions it is most likely from a target.

The recording paper is either of dry or moist. Of these, the moist type has the largest dynamic range, i.e. the highest number of discernable shades between no marking and full saturation. The reduced dynamic range of dry recording paper is partly offset by greater ease of handling.

Special search programmes are adapted to provide an efficient survey of an area.

Best coverage in long range search is attained with the side-to-bow search programme. The transducer is then trained in steps of approximately 5° from somewhere abeam on one side towards forehead and approximately 5° beyond. From there the transducer is trained continuously at full training speed in the same direction to

somewhere abeam on that side, from where it reverses and trains in steps towards forehead. Optimal turning point on sides is determined by cruising speed.

Stabilized beams

One of the operational difficulties of shipborne sonar is ship movement. When the ship is pitching and rolling or when the course is altered, it is hard to maintain sonar contact with a school of fish. Present day searchlight sonar of the more advanced type provides azimuth stabilization and correction for pitch and roll.

The best coverage in short range search is attained with the transducer continuously training from side to side through forehead. Optimal training speed is dependent on cruising speed and required range for best coverage.

Closing in on a school of fish with which sonar contact has already been established, is usually carried out with the transducer training continuously within a narrow sector. This sector may be continuously repositioned manually to provide best coverage during the entire "Closing in" phase.

Other types of sonar

For merely finding out if fish are present or not, the searchlight sonar is adequate. But when more detailed information is required, such as the movement of fish within a school, the behaviour of the school or fish migration etc., the searchlight sonar is inadequate. So in fisheries research different sonar systems are being tried out.

Scanning sonar. By insonifying a wide sector (the whole school) and then scanning the sector with a narrow receiving beam, simultaneous information from a large sector is obtained with good resolution (Tucker and Welsby, 1964).

The principle of sector scanning has particular advantages in studies of fast moving targets. The complexity of the system is, however, relatively high and the required resolution can only be obtained at a relatively high operating frequency, thus limiting the useful range.

Continuous transmission frequency modulated sonar (CTFM). In CTFM a continuous, frequency-swept signal is transmitted. A received echo will have a frequency different from the frequency transmitted at that particular instance.

The difference in frequency between the transmitted and the received signal at any instance is used to determine the range.

The greatest advantage of this system is the possibility of continuously watching a large sector. The greatest disadvantage is crosstalk, high level of reverberation and relatively short range.

Variable depth towed sonar (VDS). In certain cases it may be advantageous to use a towed sonar transducer. The transmitter and receiver transducers are then towed at optimum depth for maximum range under the prevailing sonar conditions. It is further possible to obtain lower self noise and higher cavitation limits. The technical and operational problems associated with VDS are great, and the system has so far had few civilian applications. Systems of this type have, however, been developed during the past few years for studying trawls under operational conditions.

Side looking sonar. It is known that there often is a relation between the sea bed topography and fish aggregation. The side looking sonar utilizes a fan shaped beam which is very sharp in the horizontal plane and wide in the vertical plane. By signal processing and subsequent presentation on a graphical recorder a picture of the bottom is obtained. The best results are obtained with the transducer positioned at a certain distance from the bottom. In order to keep the transducer at this distance with varying depths the transducer has to be towed.

Range performance criteria

To assess the potential capabilities of a specific sonar equipment or to compare similar equipment, a brief discussion of the sonar equation seems justified. The echo ranging capability of a sonar equipment may be estimated by reference to known quantities, the so-called *sonar parameters* which are listed below:

Source level (*SL*), the maximum sound pressure level in the transmitted pulse one metre from the transducer.

One way transmission loss (*TL*), which is represented by the spherical spreading loss and the absorption loss, the latter being highly frequency dependent.

Target strength (*TS*), describes the reflecting properties of the target.

Noise level (*NL*), which is composed of equipment self noise, ambient sea noise and ship's self noise, represents one of the major limitations to the performance of a sonar equipment.

Detection threshold (*DT*), represents the necessary signal to noise ratio for detection.

One of the several possible forms of the echo ranging equation in a noise limited case is:

$$SL - NL = 2\,TL + DT - TS$$

It is not the object of this paper to present a thorough discussion and solution of the sonar equation. This is very well covered in standard textbooks (e.g. URIC, 1967).

What should be pointed out, is that the solution of the sonar equation does not give the complete answer regarding the suitability of a certain system for the many different applications. The operational usefulness of a sonar system may in a decisive manner be dependent on the practical design and arrangement of the following important parameters: Line density and scale range of the display, automatic search programmes and data transmission, amplification characteristics, range and bearing resolution, operational features, etc.

APPLICATION OF SONAR IN FISHERIES

Although reliable statistics of sonar installations in the world's fishing fleet are unavailable, it is believed the number has passed 5,500.

The types range from simple echo sounder devices installed for horizontal ranging to high performance

automatic sonars with streamlined, retractable domes and a narrow beam stabilized against the ship's roll and pitch.

All these installations belong to the searchlight sonar family. The sound beam of all can be pointed in different directions around the ship—scanned around—and they are thus by some wrongly referred to as scanning sonar.

Other sonar types are used—some of them successfully—in fisheries research vessels and might find application on fishing vessels in the future. These types are:

Scanning sonar

Continuous transmission frequency modulated sonar (CTFM)

Variable depth towed sonar (VDS)

Side looking sonar

The wide range of searchlight sonars for fisheries can be put in different groups according to: size, price, operating range, performance, type of fishing etc. For the present review the following grouping was found logical:

Short range, hand operated

Medium range, automatic

Long range, automatic, medium speed

Long range, automatic, high speed

Short range, hand operated. Echo sounders for horizontal ranging are used in small boats down to 17 ft such as the fishing master boat in Norwegian purse seining. This simple equipment is also used on vessels up to 100 ton or more. The working range is short (normally about 200 m) and the equipment is constructed for low cruising speed (less than 8 kn).

Medium range, automatic. The second group of sonars is of the automatic, medium range (approx. max. range 1,000 m) type sonar without dome. This can be used at up to speeds of about 12 kn, but at speeds above 9 kn noise due to water passing the transducer may reduce the working range substantially. This type is used by medium sized (50 to 200 ton) purse seiners and by pelagic and bottom trawlers.

Long range, automatic, medium speed. The third group is the type which has automatic search programmes, remote tilt control and special features to ease operations in the catching phase. The transducer is mounted inside a dome. Maximum operational speed is approx. 10 to 15 kn, and maximum range is up to 2,500 m. This type is used by bigger purse seiners, and by pelagic and bottom trawlers.

Long range, automatic, high speed. The fourth group has a streamlined—fixed or retractable—dome giving this type of installation a maximum operational speed of 20 kn. The operational range often exceeds 2,500 m, and the controls are made very flexible giving the operator the opportunity to adjust the instrument to suit a variety of conditions. This group may also be fitted with stabilized sound beam and is used by research vessels and the more modern purse seiners and trawlers.

Within group 2, 3 and 4 are found some types of sonars which differ from the usual design. An example of this is the Whale Sonar. This sonar belongs to the third group but has a different hull unit construction. The dome is streamlined and non-retractable. The whale catcher uses the sonar to keep in contact with the whale at close ranges pointing the gun at the same bearing as that of the sonar contact.

The high frequency stabilized beam sonar should also be noted. This is a typical short range instrument, but has the advantage of a higher resolution than ordinary sonars. This type is in use on shallow water trawlers for observation of the character of the bottom to avoid damage to the nets. Some purse seiners also use this type of instrument.

Use of sonar in fisheries differs considerably in various parts of the world.

Five important factors which govern success or failure can be summarized as follows:

1. The sea—poor or good sonar conditions
2. The fish—present or absent, behaviour
3. The sonar and its installation—good or bad
4. The ship—noisy or quiet
5. The man—knowing his job or not

In many areas sonar is not successfully used although factors 1 and 2 are positively fulfilled. Fisheries often have old traditions which it takes time to change, and dealing with sonar requires a high level of technical know-how.

The present economy and type of vessel already in use and facility for training are also among the factors which govern the rate of growth of sonar in certain areas.

The predominant use up to now has been to detect comparatively dense fish schools close to or at the surface. Developments during later years have led to sonar being applied also in many other aspects of fisheries. Today sonar is no longer used for fish detection only. The instrument in the catching phase of purse seining and trawling today is playing a very important role—as in fact it has become an indispensable tool.

Sonar in purse seining

The purse seining fleet in the North East Atlantic was the first to use sonar. Gerhardsen (1946) and Devold (1951) described its use in fishery research.

The very first trials with horizontal ranging in commercial fisheries were carried out with an ordinary echo sounder connected to a transducer installed for horizontally ranging, and encouraging results were obtained. The Norwegian purse seine vessel *Ramoen* is believed to be the very first fishing vessel to purchase a proper fishery sonar in 1953. Jakobsen (1964) reports that small horizontal transducers were first installed in Icelandic herring boats in 1954 to 1955. They were connected to ordinary echo sounders normally used for vertical sounding. With their very limited range they could not locate new herring grounds. In an area of rich concentrations, however, schools were frequently located, and experiments in shooting the purse seine net around such schools began as early as 1954.

Today this type of installation is called BASDIC. It is still playing an important role in many fishing operations such as in small master fishing boats used by the Norwegian purse seiners when fishing for mackerel in the North Sea. The mackerel is then first detected by sonar on the main vessel, and at close range (approx. 200 m) the small boat with BASDIC is launched. The fishing master in the small boat keeps sonar contact with the mackerel school on the BASDIC, and his job is now to find out the speed and the direction of movement of the school. By radiotelephone he then directs the main vessel into a setting position and the setting begins. This procedure has proved successful, especially in fishing for mackerel which is rapid and easily scared.

The method is also often used on other types of pelagic schooling fish where many purse seiners compete for the same schools. Fishing masters with tradition in purse seining swear to this method because, they say, movement of the fish is evaluated much faster in the small boat than on the main vessel.

The sonar on the main vessel is primarily used for detecting deep swimming schools. When a school has been detected, sonar is used to estimate its extension and density. Because of variable sonar condition this estimate is always done at short range (200 to 400 m). If the size is suitable for catching, vessels which do not use a fishing master boat, use the sonar to provide further information about range, bearing, depth and movement of the school, and from this information calculation of the setting is made. In the catching or setting phases the sonar gives continuous information of range and bearing.

This procedure is today used by purse seiners all over the world. In some areas use of sonar has been adapted only recently and is in many cases not fully utilized. Sonar has also been adapted by tuna purse seiners. It has not been particularly successful in detecting tuna, but it has been found very useful in keeping contact when the fish dives at close range, using the same method as herring purse seiners use in the catching phase.

Behaviour of fish varies greatly for different species; also within one species are found variations in behaviour with seasons, physiological state and fish sizes.

Knowledge about fish behaviour is of great importance to ensure proper use of acoustic instruments, especially in catching. An example of this is: A skipper on a capelin purse seiner in the Barents Sea during winter knows that capelin is generally found in compact schools at a reasonable depth and is not easily scared by noise from ship and gear. He also knows that sonar conditions in this area during winter time are generally good. Therefore the skipper knows he can use maximum range, and the optimum tilt on the sonar transducer is approx. 3 to 5° down according to ship's trim. The fish is not easily scared so the skipper is relatively free to manoeuvre the ship without too much risk of missing the catch.

A different situation is found when purse seining for mackerel in the North Sea during summer. Then the mackerel does not show a regular day versus night pattern of behaviour. It can be found in compact schools which may suddenly disperse into not-fishable layers. The vertical migration is often very rapid, and this type of fish is also easily scared when approached.

Sonar conditions in the North Sea during summer are generally poor so that sonar range is reduced. Speed of the ship must therefore be reduced to secure maximum coverage by sonar. Reducing speed also avoids scaring the fish by vessel noise. The tilt control should be used very frequently so as not to let fish schools slip below the sonar search beam.

These two brief examples are not unusual. Similar patterns of behaviour can probably be found in different species all round the world. The use of sonar must thus be adjusted to the special behaviour of the fish being sought.

Vessel speed in limiting detection

The factors which govern maximum speed of the vessel when surveying and detecting are:

The type of sonar in use

The sonar conditions in the sea

The self noise of the ship

The type of sonar in use and self noise are known. Sonar conditions may be roughly estimated by observing the strength of any false echoes such as bottom echoes, wake echoes and reverberation (when searching in deep water).

The pulse repetition rate or sonar range should be adjusted to suit estimated working range. This estimate is necessary, because, if the ship is cruising during sonar ranging there will always be some uncovered "pockets" in the sonar area, and the size of the "pockets" increases with the speed of the ship. By using a longer range setting than actual detection range determined by sonar conditions, there would be unnecessarily great uncovered areas around the ship where schools might escape detection.

In practice vessels with low or medium speed sonar usually steam at full speed to expected fishing grounds without using sonar. On arrival, transducer is lowered and search begins. Ships with high speed sonars and low self noise use sonar when steaming at full speed and are often first to locate new areas of fish concentrations.

Tilt control should be set to the angle which allows the main part of the sound beam to cover the volume of water where fish is likely to be found.

When contact is obtained, the first job of the operator is to try to identify the target. If the echo is received at long range, the ship's course is altered to the bearing of the sonar contact, and when the range is reduced to 400 to 500 m, ship's speed is reduced to slow. Automatic searching control should then be changed to manual control, and the skipper starts evaluation procedure. Purse seine skippers hunt mostly for compact schools and should therefore be able to distinguish between different kinds or types of target.

In practice it is very like being blindfold with a stick in the hand. Instead of the stick the sonar beam is used to feel the size and characteristics of the target.

Estimating abundance

There is a close relation between the density of a fish school and strength of the echo. Estimation of echo strength will only be approximate since we do not know very much about the reflective capacity of fish. Varying

sonar conditions also complicate this estimate. One way of estimating the density of a school is: target is approached to a distance of 200 m or less. The skipper then reduces pulse length, receiver gain and, lastly, transmitting power. If echo strength fades away rapidly for only small reductions of receiver gain, the school is not dense. With dense schools echo strength keeps up with the shortest pulse length, low receiver gain and reduced transmitting power.

Target movement can be listed among the most difficult problems for a sonar skipper. It is well known that the "Doppler effect" is used to give indication of the relative movement of a target. The doppler effect is the change of pitch of the sonar echo relative to the transmitted pulse. A fish school is generally a very slow moving target and gives therefore small pitch changes which are very difficult to observe.

The changes in range and bearing from a stopped ship is another way of observing school movements. This method is difficult to practice when a number of vessels operate on a relatively limited ground. A third method often used is to circle around the school at a distance of approx. 200 m and measure changes in distance between the echoes from the propeller wake and the echoes from the school.

Sonar in the catching phase

After detection, identification, abundance estimation and observation of target movement, the skipper decides to set on the school. The sonar is now used to find bearing and distance to the school. This is called close range instrument navigation.

An experienced skipper (Gislason, 1961) has compared shooting by sonar with learning to ride a bicycle. As skill increases with practice, soon the balance is so secure that one finds it difficult to imagine ever shooting a purse seine without the aid of sonar.

Relative movement between fish schools and the ship at close range (200 m) is rapid compared to relative movement at long range (1,000 m). This means that the transducer must be trained rapidly and continuously across the target in order to keep up with the rapid relative movement of school and ship. The rate of flow of information should be as high as possible. This also means that the highest pulse repetition frequency (PRF) should be used.

Sonar in trawling

Sonar is also used in pelagic and semi-pelagic trawling and in some areas even in bottom trawling. Captain Drever (1968) reports about spotty distribution of cod in Greenland waters where echo sounders are of little or no use, but where sonar could be a decisive tool for catching schools with a bottom trawl. Captain Muschkeit (1968) reviews the use of echo sounders in trawling and finds that it is painfully obvious that the echo sounder is being asked to perform two distinct tasks: to provide information about the sea bed, which it does very well, and to say if fish is entering the net—which it cannot do so effectively. Captain Muschkeit here points to the "netsonde", the instrument which has made pelagic trawling payable. Effective pelagic trawling requires information of the fish ahead of the trawl. This obviously the echo sounder cannot do, but the sonar is made for this type of task.

Netsonde equipment has also been modified to include horizontal ranging. Appropriate acoustical equipment on a modern trawler would then be:

1. Long range sonar (a) for detecting fish, (b) for correct aiming of the vessel towards the best fish concentration when trawling, and (c) to give early information of the depth of the fish.
2. An echo sounder to inform of the general condition of the sea bed, and of the depth of the fish when the vessel is passing over.
3. Horizontally Ranging Trawl Viewer mounted on the trawl to give information needed for correct aiming of the trawl mouth toward the best fish concentration.
4. Vertical sounding device on the trawl mouth to give information about correct trawl depth and of fish entering the trawl.

Pelagic trawling

The importance of sonar for pelagic trawling should be obvious. Purse seiners and pelagic trawlers are often fishing in the same area on the same species. The detection problems should therefore be the same. When a trawler has detected a school of fish, he will have to approach the fish concentration to find the fish depth either by passing over the fish using the echo sounder or use the tilt setting of the sonar at short range for rough depth estimation. The trawler then has to steam away from the fish to allow for shooting distance and sinking time of the trawl. Before the otter boards are released the ship's course is altered to the sonar bearing of the fish concentration. During the approaching period the skipper is kept informed of the correct bearing by the sonar. As the vessel closes in, the transducer is tilted to maintain contact with the school until it is beneath the ship where it is registered on the vertical sounder and the trawl depth adjusted to the correct fishing depth. The correct depth is often difficult to judge. Muschkeit (1969) maintains that: "It should always be remembered that the lower 20 per cent of echo trace from a shoal is not fish, but a 'tail' on the lowest echo". At this stage of the catching phase the skipper needs a maximum flow of information about the fish movements in order to make final adjustment of the trawl.

The fish is now passing out of the beam of the vertical sounder, and the sonar operator will find it difficult to maintain contact through the aerated propeller water astern.

Horizontally ranging trawl viewer mounted on the trawl would perhaps fill the shortcoming of information in such a situation.

Netsonde manufacturers have been trying out netsonde versions with four transducers—one pointing upwards, one downwards, and two transducers pointing forward; the forward pointing acoustic beams being offset 10 to 20° vertically. These two forward beams may be individually presented on a "split" cathode ray tube (CRT) divided into a "port" and "starboard" presentation (Muschkeit, 1969). This complicated netsonde was

designed primarily for fishing on small, concentrated schools, but in my opinion the twin transducer type is generally to be recommended.

When the fish is distributed in layers over wide areas, the twin transducer netsonde on the trawl together with the vertical sounder onboard will probably provide the skipper with enough information sufficiently early to carry out the necessary corrections of speed, course and depth of the trawl.

A trawl viewer with six transducers has also been tried out for this purpose. This type is fitted with four transducers pointing forward, of which two are offset 10 to 20° vertically and two are offset 10 to 20° horizontally. The four transducer beams are presented on a CRT divided into forward looking up and down port and starboard.

This will give the skipper a view of the situation as seen from the trawlmouth.

The vertically mounted up and down transducer beams are operated separately and are presented on either a paper recorder or a CRT.

Bottom trawling

It is well known that different species of fish are found in clusters on the bottom; this type of behaviour is often seasonal and perhaps related to certain areas. Long range sonar for detecting such schools and aiming the trawl toward them could be important in conjunction with echo sounders to provide information about the fish and depth. A trawl viewer on the headline of the trawl to inform whether the trawl mouth is correctly pointed toward the school would also be valuable.

Sonar in bottom trawling is also used to avoid objects on the bottom. This is done in shallow water areas where rocks and stones are known in limited spots.

FUTURE TRENDS

It is clear that fishery sonars of today are called upon to perform tasks which these instruments cannot do to the satisfaction of the user.

It is also apparent that the large number of controls and constant flow of information especially in the catching phase is too much for the already fully occupied skipper on the bridge.

The fishery sonars of the future should therefore solve the following problems:

1. Quicker and more reliable fish detection by increasing the search field and solve problems connected with operation, (a) in bad weather, and (b) at greater depth.
2. Make identification easier.
3. Make the abundance estimation easier and more correct.
4. Indicate the movement of the target correctly and rapidly (e.g. high frequency Doppler sonar).
5. Relieve the skipper of some of the work of processing the flow of information in the catching phase.

To solve the above mentioned and other problems concerning future trends for sonars in fisheries, it is quite obvious that more research effort is needed. There is also a need for better contact between research workers, practical fishermen and the makers of fisheries sonars.

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Possibilities and Trends for Future Development of Sonar

D. G. Tucker

Possibilites et tendances concernant le developpement futur du sonar

Il est évident que le sonar a un rôle de plus en plus important à jouer dans les années à venir, aussi bien en ce qui concerne la recherche halieutique que pour la pêche proprement dite. L'apparition de la microélectronique a rendu posible la fabrication, à un prix bien inférieur, de sonars beaucoup plus perfectionnés et sûrs que par le passé, et on peut donc s'attendre raisonnablement à une utilisation accrue de ces appareils et à leur adoption dans des domaines où ils étaient inconnus jusqu'à présent.

Il se dessine une tendance marquée vers l'utilisation de sonars à plus grande résolution angulaire, aussi bien de grande portée (de l'ordre de 500 à 1,000 mètres) que de très faible portée (environ 20 mètres). Dans ce dernier cas, la résolution généralement prévue dans des sonars bon marché conçus pour un but déterminé est suffisamment élevée pour permettre la résolution d'une cellule de 5×5 cm^2 sur une portée de 20 mètres, ce qui rend plus facile une comparaison des observations visuelles et acoustiques Il est probable qu'en eaux troubles, l'emploi du sonar sera préférable à la vision directe, même pour des distances très courtes, et les submersibles dotés de sonars peuvent se révéler plus utiles que les submersibles avec équipage pour les recherches sous-marines. En ce qui concerne les distances plus importantes, on étudie actuellement les assemblages focalisés ainsi que l'emploi des inter-actions d'ondes acoustiques non linéaires.

A côté de la tendance vers les sonars à plus forte résolution, on note une demande pour l'information tridimensionnelle. Elle peut être obtenue par des systèmes de balayage croisé ou de balayage total, mais dans les deux cas la représentation de l'information constitue un problème très difficile.

On peur prévoir l'emploi de sonars à forte résolution installés sur la côte, de très grande portée, pour l'observation de bancs de poissons à une distance maximale d'environ 20 km. Ces sonars devraient opérer à des fréquences très basses (probablement inférieures à 5 kHz) et seraient relativement onéreux.

Le sonar ayant une bande de fréquences très large, capable de représenter la réponse de fréquence d'une cible dans un rapport de gamme de fréquences de peut-être 10 à 1, devient une possibilité réalisable et peut servir à identifier le poisson d'après sa taille.

D'autres applications plus lointaines du sonar, telles que le sonar à anomalie de champ, sont également à l'étude.

posibilidades y tendencias del desarrollo del sonar en el futuro

Es evidente que en lo futuro el sonar desempeñará un papel cada vez más importante tanto en las investigaciones sobre pesquerías como en la pesca misma. La llegada de la microelectronica ha hecho posible la fabricación de equipos de sonar más complejos y precisos a precios muy inferiores a los que era posible conseguir en lo pasado y, por tanto, es razonable esperar que el empleo del sonar aumente y se extienda a campos en los que en la actualidad aún no ha penetrado.

Hoy se tiende a lograr en los aparatos de sonar una definición angular más elevada, tanto a grandes distancias (del orden, por ejemplo, de 500–1,000 metros) como a distancias muy reducidas (alrededor de 20 metros). Por lo que se refiere a estas últimas, hoy se planea la construcción de aparatos de sonar de bajo costo especialmente diseñados para el fin concreto a que se destinan, que permitan definir una célula de 5×5 cm^2 a 20 metros de distancia; esto induce a la comparación de la observación óptica (por ejemplo, visual) con la acústica. Es probable que en aguas turbias el sonar resulte preferible a la observación óptica, incluso a distancias muy cortas, y los sumergibles guiados por sonar pueden demostrarse más útiles para las investigaciones submarinas que los sumergibles tripulados. Para distancias mayores, está en estudio el empleo de sistemas direccionales y de intersecciones de ondas acústicas no lineales. La tendencia a una mayor definición de la imagen va acompañada por una demanda de información tridimensional, que puede obtenerse mediante sistemas de líneas de exploración entrecruzadas o mediante un sistema de exploración reticular, pero en ambos casos la representación de la información plantea unproblema muy difícil.

Se puede prever el empleo de aparatos de sonar de definición muy perfeccionada y gran alcance de detección, emplazados en la costa, para observar bancos de peces a distancias de hasta 20 kilómetros. Dichos aparatos tendrían que operar a frecuencias muy bajas (probablemente menos de 5 kHz) y su funcionamiento resultaría relativamente costoso.

Un sonar con una banda de frecuencia muy amplia, capaz de representar la respuesta de frecuencia de un blanco con una relación de diez a uno, por ejemplo, en la gama de frecuencias, está convirtiéndose en una posibilidad real y puede ser interesante para la identificación de los peces por tallas.

Están también en estudio otras posibilidades más remotas, como, por ejemplo, el sonar de anomalía de campo.

THE pace of development in the field of sonar systems for civil applications has been increasing rapidly, and a good deal of research is being undertaken. Purpose of this paper is to describe some of the sonar developments now under way which may influence fisheries. Modern trends in electronics are having a profound effect on the design of sonar equipments. Other developments are also of importance, but will probably be more useful in fisheries reasearch than in fish-catching.

MICRO-ELECTRONICS INFLUENCE DESIGN

Up to only a year or two ago, the emphasis in design of sonar equipments has been strongly on a simple electronic system, using a fairly small number of components. Electronic complexity led to high cost and poor reliability. Especially for equipments used at sea, it was never easy to obtain reliability. While electronic systems were made up of individual components soldered into a circuit, it was inevitable costs of production and maintenance would be high. This insistence on simplicity led to sonar equipments in fishery being of a very elementary type. Basically only systems with single (sometimes double) beams and mechanical "scanning" (or rotation) over a search sector have been used. The slowness of mechanical scanning has prevented the use of very narrow beams and thus of high angular resolution. Most refinements introduced have been for improving detection, but not for providing faster or more effective search, nor for improving delineation of fish schools.

For research sonars, however, much more sophisticated systems have been developed, such as the within-pulse electronic sector-scanning (WPESS) sonar (Tucker, 1959; Tucker, *et al.* 1959; Tucker, *et al.* 1964; Welsby, *et al.* 1963). This was pioneered in its design and application for civil purposes by the author's Department in the late 1950's and has lately been coming into more prominence (Volgis *et. al*, 1966) since a versatile ship-mounted equipment has come into use. In this type of system a wide sector is insonified by each transmitted pulse, and a

narrow receiving beam is swung, by electronic arrangements, very rapidly across this sector—so rapidly indeed that the whole sector width is examined for echoes before the acoustic pulse has travelled its own length through the water. In this way the whole sector is examined on every transmitted pulse. Thus the search rate is very high. This enables very high angular resolution to be achieved, of an order quite impracticable in mechanical-scan sonars since the use of narrow beams (e.g. 1°) in these leads to very ineffective search (Tucker, 1967).

The use of WPESS sonar is very beneficial in the study of fish behaviour (Tucker, 1967), in observing the behaviour of underwater gear, in monitoring and directing the movements of divers, etc. For some of these applications the acoustic frequency is made high (e.g. 500 kHz) so that very high resolution, e.g. 0.5° in angle, 7.5 cm (3 in) in range, can be obtained using only small transducers; the maximum range is then relatively small, perhaps only 60 m (200 ft) on a 500 kHz equipment, or 200 m (650 ft) in a 300 kHz equipment. On the other hand, the system can equally well be used at lower frequencies, and in the early trials (Tucker, 1967), 37 kHz was used with a range of detection on small fish schools of nearly 800 m (2,500 ft).

WPESS sonar would be attractive in fish catching operations if it were not for the high cost in existing designs—due to two factors:

1. The possible need for some kind of stabilizing gear for the transducers when very high angular resolution is used, and the equipment is mounted on small ships subject to large amounts of roll and yaw.
2. The complexity of the electronic system.

The extent to which stabilization is needed depends very much on the application. It is thought that for WPESS sonar used for searching for midwater fish at moderate ranges, the need for stabilization is small and a completely unstabilized transducer mounting would be acceptable. But, for searching for demersal fish, within perhaps 3 or 4 m (9 – 13 ft) of the sea-floor, using the vertical-scanning technique proposed by the Fisheries Laboratory at Lowestoft, now being tested by them at sea on R.V. *Clione*, and demonstrated in principle by the author and a colleague (Tucker, *et al.* 1964) in 1963, a high degree of stabilization is essential.

In the pre-micro-electronics era, estimates of £10,000 or more for electronics ruled such equipment out from commercial fishing.

Use of digital micro-electronics

The comparatively recent introduction of micro-electronics and integrated-circuit technology is rapidly revolutionizing the approach to the design of electronic systems (Creasey, 1970). About five years ago, there became available, at rapidly reducing prices, miniature electronic units or integrated circuits in which a complete basic circuit, equivalent to perhaps a dozen discrete components, was provided in a volume no larger than that occupied by a traditional single small component. These units were not a miniature assembly of microscopic discrete circuit elements, but were instead of "monolithic" form in which the circuit was formed as a whole in a small piece of silicon by various diffusion processes. The basic cost of the unit was almost neglible if sufficient quantities were made; the real cost was that of testing and encapsulating. This is still the position. It is moreover possible to incorporate these units into thin-film or thick-film integrated circuits, which although not miniature, can be made very cheaply if quantities are sufficient. However, for the quantities involved in the likely sonar markets, it would be cheaper to use the monothilic units soldered into ordinary printed-circuit boards.

The micro-electronic units which first became available were of digital type; in other words they represented circuits which had functions of the type used in digital computers, i.e. primarily switching or "on-off" functions, and not those associated with linear amplifiers, frequency changers, filters, etc., which are called analogue circuits.

The impasse, where the functions of within-pulse electronic scanning sonar would be valuable in fishing operations but the cost of the electronics was prohibitive, seemed to have only one solution: to design the electronic system in such a way that micro-electronics could be used. At the time this meant designing the sonar to use digital circuitry throughout—and this meant a fresh approach to the principles of sonar design.

This was undertaken in the author's Department, and the "Digital Sonar" is the result (Nairn, 1968; Creasey, 1969). The cost has been reduced about tenfold as compared with the previous WPESS sonar designs, and the sonar is expected shortly to be available commercially.

In this sonar the receiving transducer array is, as in other scanning systems, divided into sections. The signal received from each section is amplified and chopped to a predetermined level, so that only the zero-crossing positions remain to give information about the signal. Short pulses are generated at each zero-crossing, and by means of counting circuits driven by a fast clock-pulse, the time differences between the pulses on each pair of adjacent channels are measured and recorded on the digital counting circuits. If there is no background noise, but only coherent signal, then these differences will be the same for all pairs of adjacent channels, and the magnitude of the difference will define the direction from which the signal has come. If, however, there is no coherent signal, but only background noise, then the differences will be random. The average difference is therefore measured by the digital circuitry in order to determine the bearing of a signal; and the departure of each individual difference from this mean is also measured and the average of these over the whole array is determined, so that if it is too large, the sample may be rejected as not representing a true signal. This whole process is repeated every two or three cycles of the received wave, and if consistently low average departures are obtained, the wave is accepted as signal. A bright-up pulse is then given to the B-scan display at the bearing position determined by the average difference, and, of course, at the correct point in the range scale.

It will be seen that the digital sonar operates quite differently from the "analogue" WPESS sonar, and it is therefore not surprising that its performance differs in a number of ways. In particular, it is less able to deal adequately with several targets at exactly the same range

but on different bearings, and it cannot give as good detection in the presence of strong reverberation. Nevertheless, over a large number of trials in various situations, both shore-mounted and ship-mounted, it has given a consistently good performance and has not seemed inferior generally to the analogue WPESS sonar.

The present digital sonar system operates with an acoustic frequency of 50 kHz (which involves clock pulse rates of 6 mHz) and various transducer arrangements have been tried for different applications. For fish catching operations a sector width of about 60° horizontally (with scanning in the horizontal plane) seems appropriate, with a vertical beam width of perhaps 10 or 15°. For use with vertical scanning, a sector width of about 10° is appropriate, with perhaps also a 10° horizontal beam width. In these arrangements the range of detection of small schools of fish would be about 1 km (1100 yds), although larger targets have been detected out to about 3 km (2 miles).

In using the digital sonar one cannot talk about angular resolution, or beam width of the receiving beam, in the same way as in the analogue WPESS sonar, as the whole basis of operation is different. In the absence of noise, the resolution of the digital sonar is far better than that of the analogue sonar, although in the presence of very severe noise or reverberation it would be worse. In general the digital sonar has been found a very versatile instrument, and in good conditions gives as good resolution as an analogue WPESS sonar operating on a much higher frequency and therefore having very much shorter range.

In the hope of obtaining still better resolution, although at the expense of shorter range, work is proceeding on the design of a 500 kHz version of the digital sonar, which involves clock pulse rates of 60 mHz. This has now become possible because of recent availability of suitable micro-electronic units. It is evident that continuing improvement in performance of micro-electronic units will lead to ever-greater flexibility in the design of digital sonars for special purposes.

Further development of analogue WPESS sonar using micro-electronics

Various types of analogue circuit are now becoming available in micro-electronic form, and in particular there is available a range of operational amplifiers. An operational amplifier is the basic element of an analogue computer, and is essentially a high-gain amplifier of restricted frequency-range and with various kinds of feedback. It is useful in several ways in sonar signal-processing. The analogue WPESS sonar also requires modulators and filters for frequency-changing, ordinary amplifiers, and sometimes multipliers. Modulators are available in micro-electronic form, with a satisfactory performance, and so are some amplifiers. Some of the amplifiers available are, moreover, suitable for use with automatic and time-varying gain control, which is important in sonar. Filters still represent a problem, however, and the inductance-capacitance filter which has formed the basis of so much communication and electronic equipment in the past is quite unsuitable for realization in micro-electronic form because inductors cannot be made by diffusion and such-like processes. Active filters using resistances, capacitances and transistors can be designed and can be made in some types of integrated circuit. "N-path" filters are another type which might find an application in sonar.

It is clear that it is just becoming feasible to build an analogue WPESS sonar in micro-electronic form, and in the author's Department the system of WPESS originally developed there is being re-designed and a new model is being built using micro-electronics. This will almost certainly prove a more reliable and certainly a cheaper form than the original, and much smaller and lighter. But it is not at present possible to get the cost down enough to make it commercially competitive with the digital sonar. It is, however, hoped that there will be enough demand for it, in applications such as forward search for demersal fish where the digital sonar has serious limitations, to warrant its commercial production. The design of the electronic system is such that a wide range of acoustic frequencies and transducers can be used with it, with only minor changes in the electronics.

Other micro-electronic systems

The digital micro-electronic units used in the digital sonar involve transistors of the bipolar type, so that although made as part of an integrated circuit, they are basically the same transistors as used in the earlier types of equipment. Another kind of transistor, more recently available commercially, the MOST (metal oxide silicon transistor), has attractive characteristics for many applications and has the particular advantage that it lends itself more easily and cheaply to integrated-circuit production, and permits a larger number of circuit elements per unit area than the bipolar transistor. It therefore has particular applications where an electronic unit is required with a vast number of interconnected elements but only relatively few external connections. Such a unit is a shift register, and on this unit can be based a valuable sonar signalling-processing function, the correlator. In most sonar work the speed of operation required from circuits is limited, a frequency response up to a few hundred kHz being adequate. Although MOSTs are slower in response than bipolar transistors, they are adequate for this sonar range, and so the integrated-circuit MOST shift-register can be used in sonar.

In fisheries work, there may well prove to be some application for correlation methods of detection. Put very simply, the system would transmit a relatively long interrogating signal, comprising perhaps a sequence of pulses. The receiver would amplify and then clip the signals as in the digital sonar. The correlator would then give a short single-pulse output when a received signal had the same sequence of pulses as that transmitted. Very good discrimination against noise and reverberation is obtained by this system, yet the range resolution is as good as if only a single pulse element had been transmitted. A fuller account of MOST micro-electronics for this application is given by Williams (1969).

WPESS sonars for hydrographic purposes

There is a growing demand for accurate and complete surveying of shallow sea-beds, particularly in regard to the operation of large tankers. Proposals are being examined for carrying out such surveys by means of

forward- or side-looking WPESS sonar equipments. Both the information obtained, and the availability of such equipments, are relevant to fishing interests.

If a WPESS sonar is operated with vertical scan, from a point some way above the sea-bed, then its display (say a B-scan) will show the profile of the sea-bed along the sonar beam, with an accuracy depending on several factors, notably the acoustic refraction in the water, the magnitude of sound scattering from the sea-bed at very low grazing angles, and the knowledge of the transducer's altitude, stability, height, etc. Profiles obtained in this way in preliminary trials (Creasey, *et al.* 1970) in a reservoir using the digital sonar fixed to a jetty have been very encouraging.

It is clear that if such a method is adopted for sea-bed survey, then the determination of true profiles and depths will depend on quite complicated processing of the raw sonar signals so that corrections for refraction, ship's heave, etc. can be automatically incorporated in the system. This will clearly be an application for micro-electronics if the system is to be ship-borne and on-line in its action.

It will now be clear that micro-electronics are already having a profound effect on sonar design philosophy, are leading to new kinds of sonar which can be manufactured cheaply, and are likely to have an ever-increasing influence in sonar for fisheries.

TREND TO HIGHER ANGULAR RESOLUTION

There is very definite interest in obtaining much higher angular resolution in sonar than has hitherto been available. Generally there has been no difficulty over resolution in range; quite short pulses can be transmitted which enable targets to be separately detected at spacings in range which are very small compared with the width of the beam and therefore with the detectable spacing in the transverse dimension. Range resolution of less than a metre (3 ft) is commonplace in fisheries sonars, but transverse resolution is more usually of the order of tens or hundreds of metres; e.g. a 5°-beam at 500 m (1600 ft) range has a width of about 45 m (150 ft). Even a 1°-beam used in a WPESS sonar has a width at 500 m of ten times the range resolution.

There are two particular applications of sonar in fisheries where better angular resolution is needed at longer ranges. One is the observation of behaviour of fish and gear; the other is the detection of fish very near the sea-bed as required for bottom trawling.

There is also need to obtain very high resolution at short ranges, even down to a few metres. The main interest here is in observing fish entering a net and in detailed studies of behaviour of fish and gear. There are, however, numerous applications outside fisheries, such as examining underwater structures, police searches for abandoned objects and bodies in water, searches for wrecks, etc. In many cases it is desired that sonar operates from a submersible vehicle. In these short-range applications it is necessary to determine when acoustic methods give better results than optical methods, and vice-versa.

The "near-field" problem

To obtain a beam of very narrow angular width requires a transducer which has a length of many wavelengths. For example, a 0.5 degree beam (measured at its 3-dB points) requires a transducer length of approximately 120 wavelengths. To keep the transducer small, as high a frequency as possible is chosen. But the attenuation in the water increases rapidly with frequency. At 500 kHz it is in the region of 0.1 dB/m, while at 1 mHz it is in the region of 0.3 dB/m. Since there must be a specified figure for the maximum range, it is clear that the frequency cannot be increased indefinitely. Thus there is a limit to the reduction in size of the transducer. If the maximum range is to be about 50 m (160 ft), then 500 kHz would be a reasonable frequency, the wavelength would be 0.3 cm (0.12 in); and the transducer length (l) for a 0.5° beam would be 36 cm (14 in).

The concept of the 0.5° beam is, of course, a far-field one, based on the idea that the point at which it is measured is well removed from the transducer which is assumed to be a point from which the beam boundaries are drawn. But at close ranges, it is clear that the concept of angular beam width is invalid; if the transducer is straight (i.e. unfocussed) the beam can hardly be narrower than the transducer length. The far-field beam width is developed only after a range of about l^2/λ, i.e. about 40 m (130 ft) from the transducer. This is almost the maximum range specified, so that we have "near-field" operation almost throughout. The lateral resolution is therefore clearly not measurable in angle, but in distance, and is thus about 36 cm (14 in). The interesting thing is that if the transducer length were halved, the lateral resolution would be improved at ranges out to 20 m (65 ft), although the far-field angular beam width would be doubled.

The situation described is clearly very unsatisfactory. But it can be overcome by using multiplicative signal processing on reception (Welsby, *et al.* 1959). In this system the receiving transducer is divided into two, and the signals from the two half-transducers are multiplied together. Thus a target can give a signal output from the receiver only if it lies in the beams of both half-transducers; moreover the far-field beam width is one half of that corresponding to the length of the transducer used normally, and is formed from a distance of $3\,l^2/16\lambda$ outwards. Thus the near-field beam is extremely narrow, and lateral resolution of one-sixth of the transducer length (or less) is feasible (Tucker, 1968). In the example taken, the overall length of the transducer would be 18 cm (8 in), and the lateral resolution might be quoted as 3 cm (1.2 in) or 0.5° whichever is the poorer. This is clearly an enormous advantage for the multiplicative system.

One trouble with the multiplicative system is that several target echoes coming from the same range interact, and when WPESS is used this causes some difficulty unless there is fairly rapid movements of the target or of the sonar itself to cause cancellation of spurious indications (Welsby, 1968; Shah, 1968). Fortunately, in most applications there is adequate movement and good results are obtained.

Focussed beams

Multiplicative operation is often a solution to the problem of getting good angular or transverse resolution. It would not be adequate, however, for the difficult problem of the detection of fish near the sea-bed since

here the interference between sea-bed echo and fish echo would be very serious.

Another way of obtaining high lateral resolution over an interval of range is to focus the beam from a large transducer, making the resolution much better than the dimension of the transducer. If the focussing is done by means of electrical phase networks connected to the sections of a sectionalized transducer, then variations in the phases can cause the region where focussing is obtained to be moved out or in along the range axis. Moreover, variations of the phases in a different manner can cause the region of focussing to be scanned or deflected transversely. The matter has been investigated theoretically by Welsby (1968), who has a full experimental investigation in progress, using a transducer array designed to give a resolution at ranges of 100–200 m (320–640 ft) corresponding to an angular resolution of 0.1° subtended at the centre of the transducer. It has already been demonstrated (Shah, 1968) that a beam of a nominal width of 0.1° retains this width quite accurately in still, deep water at ranges of a few hundred metres; it remains to be proved, however, that this is equally true in turbulent coastal waters.

Use of nonlinear acoustic wave interactions

In the previous sections the solution to the problem of obtaining a narrow beam width has lain in having a large transducer. This is both expensive and practically inconvenient if the equipment is ship-borne. A method which can provide reasonably narrow beams using only small transducers is the exploitation of non-linear wave interactions.

That acoustic propagation is inherently nonlinear has been known for long but exploitation of this knowledge is comparatively recent. That practical applications were possible became clear from work in America early in the present decade (Westervelt, 1963; Bellin, *et al.* 1962), but the main work of exploitation has been that of Berktay and others at the University of Birmingham (Berktay, 1967). Further theoretical work has been done in Norway (Tjøtta, 1967).

The propagation of acoustic waves is nonlinear because the velocity of propagation is a funtion of the instantaneous amplitude of the wave. This arises because of two separate effects:

(i) the particle velocity adds to the nominal propagation velocity; i.e. when the particle velocity has its maximum positive value, the net propagation velocity is a maximum, and when the particle velocity has its maximum negative value, the net propagation velocity is a minimum.

(ii) the propagation velocity (apart from the above effect) is given by $\sqrt{(\kappa/\rho)}$ where κ is the bulk modulus and ρ is the density of the medium; both κ and ρ vary with the acoustic pressure and so give a propagation velocity dependent on the instantaneous wave amplitude.

Thus the (positive) crests of the acoustic wave travel faster than the (negative) troughs, and the wave at some point distant from the source becomes distorted. If it started as a simple harmonic wave, harmonics are introduced; if it was a complex wave, then intermodulation products are produced. This can be exploited thus:

Consider a square or circular transducer transmitting two closely-spaced frequencies f_1 and f_2 and having a side or diameter which is many wavelengths at these frequencies. Then a narrow beam is formed which in its near-field is approximately collimated. As the wave of two frequencies propagates along this beam, nonlinear interaction takes place and a wave of frequency f_1-f_2 is generated. The phase velocity of this is evidently correct for propagation in the same direction as the "primary" waves at f_1 and f_2, but it will not be able to propagate in other directions. One can indeed regard the interaction volume as forming an end-fire array of length very great compared with the dimensions of the transducers. Thus a highly directional transmission is obtained at the low frequency f_1-f_2 using transducers so small that at this frequency they would be practically omnidirectional. Moreover, there are no side-lobes. The practical value of this is obvious.

A great deal of theory and experiment has been done, and it is clear that for a given power and (small) transducer size it is possible to obtain as great an intensity at a given distant point by this means as by normal transmission, yet with the most important advantage of high directionality.

The use of nonlinear acoustic transmission in scanning sonar needs a little explanation. Normally, a within-pulse electronic sector-scanning sonar insonifies (on transmission) the whole sector, while a narrow receiving beam is scanned across it once in each interval of time equal to the pulse duration. To exploit the nonlinear effect in a scanning system, however, means doing the scanning on the transmitted beam while using a wide receiving beam. The difference-frequency beam (f_1-f_2) discussed above is easily deflected away from its normal direction by the use of a sectionalized transducer and suitable phasing networks at the high frequencies (f_1-f_2). It is then necessary to code the signals transmitted in the different directions so that, on detection, the direction of a target can be recognized and the echo displayed at the correct bearing. The simplest way to do this is to use different frequencies for different directions; other coding systems are being investigated. This coding, of course, demands a transmitting band width greater than is necessary for the specified range resolution in a normal system; fortunately band width is no problem in this nonlinear system, as it is readily shown to be inherently a wideband system.

An equipment now nearing completion, intended for experimental trials at sea, has $f_1 \simeq 155$ kHz, $f_2 \simeq 120$ kHz, so that the difference frequency used for the effective sonar beam has a centre frequency of about 35 kHz. The beam width in the scanning plane is about 1.2°, and it is expected that the range of detection of a single cod will exceed 500 m (1600 ft).

Acoustic v optical observation at short ranges

It is commonly thought that, for short ranges of a few metres or tens of metres, optical methods of underwater observation are necessarily superior to acoustic methods. This is a fallacy; comparison depends on circumstances, and in turbid coastal waters sonar is potentially far superior to vision, television, or photography.

Since both optical and acoustic observation is effected by means of wave propagation, it follows that both are limited by the same kind of effects. The most important propagation effect limiting observation at relatively short ranges is scattering of the waves by inhomogeneities in the water. By "relatively short ranges" we mean those where absorption losses are not very important. The wave lengths concerned are around 0.5×10^{-6} m for optics (assuming the visible range is used) and 1×10^{-3} m for acoustics (assuming a frequency between 1 and 2 mHz is used).

Although over long acoustic paths turbulence and thermal inhomogeneities may be important, these are unlikely to be significant over short paths, except in very special cases where observation is being attempted in strong eddies at the junction of water flows of different temperature or salinity. Such conditions would also disturb optical observation. Normally the inhomogeneities in water consist of particles of mineral or organic matter in suspension. These can occasionally be large, e.g. pieces of seaweed in inshore waters, but generally they are small, with maximum dimensions of the order of 2×10^{-6} m (8×10^{-5} in) in oceanic waters, rising to perhaps 20×10^{-6} m in turbid coastal waters. Concentrations may be from less than 1 mg/litre to around 20 mg/litre (Jerlov, 1968). It is obvious that these particles can hardly affect the acoustic waves at all, being so small compared with wavelength; but for light waves the particles are large compared with wavelength. It is therfore the suspended particles which dominate optical performance.

Gazey (1970) has done some experiments to determine the angular resolution obtainable in optical systems, using as detector the human eye, a television camera and an ordinary photographic camera. He used a path length of 1 m (3 ft), with a television test card as the object to be viewed, and using self-luminous object, object illuminated from above (i.e. as with daylight underwater) and object illuminated from in front (i.e. as with artificial light underwater). Turbidity of the water was obtained under controlled conditions by adding known amounts of particles of known size (about 2.5×10^{-6} m). Observation of the visibility of the variously-spaced bars on the test card gave a direct measurement of the angular resolution obtained with various degrees of turbidity. As would be expected, the best results were obtained with the self-luminous object (corresponding, for example, to a range-gated laser TV system), and the worst with front illumination. The unaided eye gave better results than the TV or photographic cameras, but the general relationship was the same in each case; so we shall quote the results for top lighting with viewing by eye. Here the angular resolution fell from about 0.01° for oceanic turbidity to about 0.2° with moderate coastal turbidity (i.e. 6 mg/litre of suspended particles). These figures apply to a range of 1 m (3 ft). In the very turbid conditions, this is also about the maximum range over which the object can be detected at all.

New sonars are currently being developed which have beamwidths of 0.1°, operating in the frequency range 600 kHz to 2 mHz, thus giving ranges of detection of about 50 m (160 ft) down to about 5 m (16 ft) respectively. It is clear that under turbid conditions these will give both range capability and angular resolution considerably superior to what can be obtained optically. Moreover, the sonar equipment is probably much cheaper. It seems that more emphasis will need to be placed on this kind of sonar development.

THREE-DIMENSIONAL SONAR SYSTEMS

Hitherto sonar sytems have been essentially one- or two-dimensional. One dimension is obtained from the range measurement, and this applies to all sonar systems (apart from passive systems used just for listening; and these we are not considering at present). A second dimension is obtained by an angular scan, mechanical or electronic, usually in the horizontal plane, but sometimes in the vertical plane.

In a one-dimensional sonar, a very suitable display is the paper recorder. For a two-dimensional sonar, the paper recorder is not suitable, and cathode-ray displays are used, with either a PPI (true plan) or B-scan (rectangular coordinates of range and angle).

It has become evident that for many purposes a three-dimensional sonar is required, giving range, bearing *and* elevation. This would be useful for searching for, and locating, midwater fish; and it would be particularly useful for tracking fish schools, submersible vehicles, divers, etc. There are several ways in which a three-dimensional ("3-D") sonar can be designed.

One system of 3-D sonar is the raster scan. Here the whole volume to be scanned is insonified by each transmitted pulse. The receiver has a Mills-cross type of array which forms a pencil beam which is swept rapidly to and fro across the sector with each successive sweep at a slightly different elevation. In this way the whole sector is covered by the pencil beam, and the whole process is arranged to be completed before the pulse has travelled its own length through the water. In practice this means that the pulse has to be rather longer than for a one-axis sweep (i.e. longer than in the existing WPESS sonars), and so range resolution has to be sacrificed a little in order to obtain the 3-D result. This would usually be unimportant as range resolution is so greatly superior to angular resolution in normal sonars. The system has been built and tested for radar application (Slattery, 1966) and could easily be used in sonar. The main problem is how to display the 3-D information.

Another way of obtaining 3-D information is to use two WPESS sonars with their scanning planes mutually at right angles. Each can have its own B-scan display, the two preferably arranged side-by-side, and best of all on the same cathode ray tube, and it is, of course, desirable for both sonars to be driven from the same range time-base. If cheap scanning sonar, such as the digital sonar, is used, this is still an inexpensive way of obtaining a very great information from underwater. It is possible that in a dynamic practical situation the amount of data presented on the display will be too much for a single operator to cope with. A system of this kind is being made, using digital sonars, for some special trials during summer 1970, and the experience gained from it will be very valuable. It is almost certain that a good deal of thought will have to be given to the display problem. It is probable that some further automatic electronic

processing of the signals will have to be devised to precede the visual display. A sonar of this dual-scan type will quite possibly be the fishing boat sonar of the future.

A good deal of research work is being done in many laboratories on acoustic holography (Metherell, *et al.* 1969), and it is only natural to ask whether this is likely to prove a solution to the problem of 3-D observation underwater. At present there seems little likelihood of its even being practical, let alone a solution to any problem, because the non-existence of a suitable image converter (for converting the acoustic field information into electronic signals) prevents the method from being capable of dealing with any but almost stationary situations. At present the acoustic field has to be explored by a mechanically scanned probe. If and when a suitable converter is produced, the method would then be practical. It is hard to see how, even then, it could compete favourably with an echo-ranging sonar since it can hardly hope to give range information of anything like the same accuracy. Its main justification probably lies in the fact that a picture obtained by holography would be the kind of picture we are used to seeing in photographs and not the range solidus bearing picture obtained with normal sonar or radar. How important an advantage this is will have to be determined by experience.

Acoustic imaging using acoustic lenses or focussing mirrors (Haslett, *et al.* 1966) has often been proposed, and has been demonstrated more successfully in other applications (Smyth, *et al.* 1963) than in our underwater ones. Apart from the difficulty of finding a suitable image converter, this is likely always to be much more expensive than sonar for a given quality of observation.

SOME OTHER SONAR POSSIBILITIES

During very extensive observations of underwater acoustic propagation between a transmitter and a receiver spaced many kilometres apart, and using a frequency of 1 kHz, it was found by Weston and his colleagues (Weston, *et al.* 1969) that fish had a significant effect on propagation at this frequency, and it was possible to make certain deductions about their schooling behaviour from this effect. These results have led to thinking about possible uses of such low frequencies in a sonar system intended to show the movements of fish schools in a large area such as a large estuary or a piece of coastal water, covering perhaps 500 km^2 (150 sq. miles). Such a system would need to have a very large receiving array—probably about 6 m (20 ft) to give a beamwidth small enough to provide acceptable delineation of fish schools, and would therefore not be suitable for mounting on a ship; it would have to be shore based but not necessarily a permanent installation. The receiving beam would need to be scanned mechanically or electronically, the transmitted power would need to be high, and it is clear that the system would be expensive. It is not certain, of course, that it would be effective, nor can one foresee at the moment exactly how useful it would be. It is to be hoped that it will prove possible for the work to be done, however, as such a project would contribute much to advancement of knowledge however successful or otherwise it proved.

Considerable experience of long-range sonar operating at 6.6 kHz is being, and will continue to be gained, by the use of the GLORIA ("Geological long-range inclined asdic") sidescan sonar built at the National Institute of Oceanography (Rusby, 1970). The new proposal would materially extend this experience.

Wideband sonar

Work has been proceeding for some years on the research necessary for the development of a sonar which not only displays the range and bearing of a target but also its frequency response over a 10:1 band width (Tucker, 1967). This work has now led to an experimental equipment which has already shown some promise (Berktay *et al.* 1968), and it is hoped that further trials of an improved equipment will prove it to be a valuable instrument. Its main application is likely to be in research, but it has for long been hoped that wideband frequency response measurement of fish echoes would give information on the size and character of the fish (Haslett, 1962).

Field anomaly sonar

It is possible, in principle, to detect the presence of objects in an acoustic field by measuring distortion of the field in terms of pressure and particle velocity or displacement changes—or, indeed, in terms of the disturbances in the acoustic wave impedance at various points. This would mean having both pressure-responsive and velocity- or displacement-responsive transducer probes at various points in the field. Very low frequencies would be used so that the wavelength is large compared with the dimensions of the observed volume. It is quite likely that this is the system used by some marine animals for exploring their environment. Welsby (1968) has examined this matter in outline, and detailed research is in hand.

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Sector-scanning Sonar Used for Observing Deep-sea Trawling

A. R. Margetts

Emploi du sonar a balayage de secteur pour l'observation des chaluts de pêche hauturiere

Ce document décrit la première utilisation pour des recherches sur les pêches du sonar à balayage de secteur du Laboratoire de recherche de l'Amirauté, installé avec stabilisation hydraulique à bord du NR CLIONE. Un film sur quelques-uns des résultats obtenus doit être présenté au cours de la Conférence de Reykjavik. Les détails des chaluts pélagiques et de fond apparaissent clairement et l'on peut détecter des poissons et des bancs de poissons.

Empleo del sonar de exploración por sectores para la observación de la pesca al arrastre en alta mar

Se describe el empleo en las investigaciones pesqueras, por vez primera, del sonar de exploración por sectores del Laboratorio de Investigaciones del Almirantazgo, instalado, con estabilización hidráulica, en el buque de investigación CLIONE. Una película con algunos de los resultados obtenidos se proyectará en la Conferencia de Reykjavik. Se ven claramente detalles de las redes de arrastre pelágicas y de fondo y es posible distinguir peces y cardúmenes de éstos.

ATTENTION was drawn by Tucker and Welsby at the 1963 FAO Second World Fishing Gear Congress to the possibilities of using an electronic sector-scanning sonar in fisheries research (Tucker and Welsby, 1964). This followed trials at sea in which an attempt was made to follow the movements of fish schools with the aid of a rather crude first form of sector-scanner (Harden Jones and McCartney, 1962). Cushing and Harden Jones (1966) described the first trials of a more sophisticated equipment employed for observing fish schools and a pelagic trawl in action. Their equipment was the Admiralty Research Laboratory modulation scanning sonar installed in P. A. S. *Gossamer*. In 1969 an improved version of that same equipment was installed

in RV *Clione*. During the past few months the A.R.L. scanner in RV *Clione* has been employed for a variety of purposes including the observation of pelagic and bottom trawls and of fish shoals.

With such new and sophisticated equipment it was only to be expected that the fisheries scientists operating it would require time to become familiar with it and to find out its capabilities. Even now the operators are still developing techniques and are far from being fully proficient in realizing the full potential of the equipment. Hence this report is very much in the nature of an interim progress report of the first fishing investigations.

THE A.R.L. SCANNER

The basic specifications of the A.R.L. scanner in RV *Clione* are mostly as described by Cushing and Harden Jones (1966)—frequency 300 kHz, transmitter beam widths 30° × 5°, receiver beam widths 0.33° × 10°, scanning rate 10,000 times/s over a sector of 30°, and transducer with 75 elements. The pulse repetition rate has been altered to be either 2 or 4/s, allowing a switch-over to be made from short 200 yards (183 m) to long 400 yards (366 m) range. Two important major changes in the equipment have both concerned the mechanical design and mounting of the transducer. First, this is now hydraulically stabilized to a very fine degree using a vertical gyro referring to pitch and roll and a gyro compass referring to yaw; secondly the whole transducer unit can be switched through 90° so that the sector scanned can be either horizontal, as in the original design, or vertical as suggested by Harden Jones and referred to by Tucker and Welsby. The switch-over from horizontal to vertical mode or vice-versa can be completed in 1½ to 4 seconds. Use of the vertical mode allows quick determination of the depth from the surface or height off the sea-bed of a target. In either mode, the transducer can be trained in azimuth and tilted by manual control.

When the scanner is operating, selected sequences on a second display screen are photographed on 16 mm film at 2 or 4 frames/s according to which range scale is in use. This is normally projected at 16 frames/s so that the films represent a times eight or times four speeding up of the original presentation. At first acquaintance the picture displayed on the screen can be very confusing, but after a short while the new observer will readily distinguish the sought-for targets from extraneous presentations and background information. Even the experienced observer must repeatedly work through the film and single frames of it to extract all the information presented. Each frame of the film shows two screens; the right hand screen shows the full picture and the left hand screen shows a selected 50 yd (46 m) piece of that picture expanded to give a times two or times four magnification according to the range in use at the time. Presented on each frame of the film are also the date, time, frame number, azimuth bearing, tilt angle, short (S) or long (L) range setting, and transducer mode (– = horizontal, 1 = vertical).

It must be remembered that the display consists of a B-scan on a rectangular CRT, thus there is some distortion of the true picture comparable to that in maps of the Southern Hemisphere on the Mercator projection. At the full range of 400 yds (366 m) the width of the top of the screen represents 200 yds (183 m), and, on short range setting of 200 yds (183 m) the width at the top represents 100 yds (91 m). At any point up from the bottom of the screen the width of the screen represents half of the range of that point.

Observations with the scanner

The recent use of RV *Clione* with the A.R.L. scanner to study trawls and fish shoals has been conducted by a team of scientists including Dr. D. H. Cushing, /Dr. F. R. Harden Jones, Mr. R. B. Mitson and the writer, Mr. A. R. Margetts.

When looking at trawls, RV *Corella* has been towing the trawl and RV *Clione* has manoeuvred over and around the trawl so as to look at it with the scanner from directly behind, from the side, from directly above, and from various intermediate positions.

Cushing and Harden Jones (1966) have already shown pictures of a pelagic trawl seen by the sector scanner. Recent sector scanner observations on a pelagic trawl have given improved pictures especially of the rope frame of the net mouth and of the wire bridles and warps (fig 1).

Fig 1. Sector scanner representation of 800 mesh circ., four panel Engel pelagic trawl above sand ridges. Above screens, from left to right, are date, time and frame number. Below screens are, on the left, transducer azimuth bearing and, on the right, transducer tilt angle. Between the screens are transducer mode indicator (horizontal or vertical) and range scale indicator (long or short)

Also, with the scanner in vertical mode and the trawl viewed from the side, cross-sectional views of the net have been obtained showing the net shape at various positions along its length. The absence of solid objects or surfaces near a pelagic trawl renders such observation fairly straightforward.

The prospects of making detailed observation of a bottom trawl were much less certain. However, first results have clearly shown that the scanner gives a very good picture of a bottom trawl in action. It is with views of a bottom trawl that the films for the FAO Reykjavik Conference is primarily concerned. The film itself is simply a series of extracts of observations of trawls; it has not been finally edited for any specific purpose.

The bottom trawl used was a small Granton of 80 ft (24 m) headline and 120 ft (36.6 m) groundrope. At various times it was used with and without bobbins and tickler chain and the bridle length was varied. The depth of fishing has varied from 10 to 50 fm (18–91 m), with the depth:warp ratio at 1:3 or 1:3.5. Trawling speed was mostly 3–3½ kn. While the clearest pictures have been obtained in the shallower depths and at shorter ranges, it has proved just possible to distinguish a trawl and identify its major components at a range of 350 yds (320 m) when fished at 50 fm (91 m) depth. At about 200–300 yds (183–274 m) all of the trawl from otter boards to cod-end can be seen in one frame.

By training the transducer suitably in tilt and azimuth the warps can be followed down from the wake of the towing ship to the otter boards. The otter boards themselves show conspicuously, especially when plane to the scanner beam; their shape and attitude can be discerned at short range, their shadows being helpful for this (fig 2).

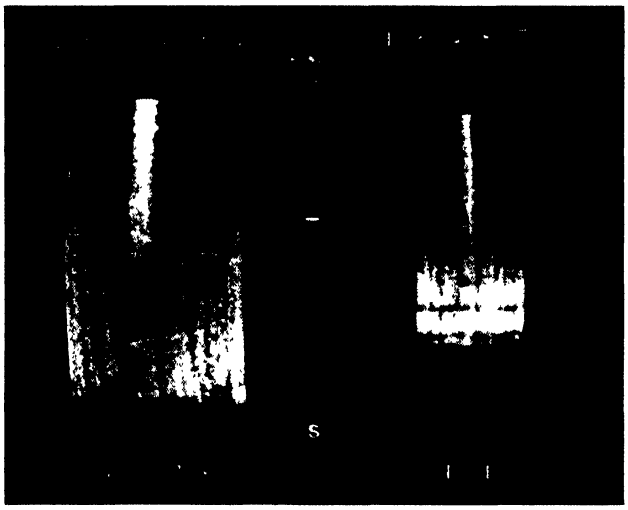

Fig 2. Sector scanner representation of port-side 9.5 × 4.75 ft (2.9 × 1.45 m) bottom trawl flat rectangular otter board showing shadow of board, backstrops and bridle. Note noise band originating from otter board

There are two conspicuous features associated with the otter boards, firstly the turbulent eddy trails (figs 3 and 5) and secondly the bands of noise that they set up (fig 2). The eddy trails show up on the sector-scanner almost as they do on cine photographs; the change in nature of these trails with changes in the sea bed that the otter boards are passing over and the position of the eddy trails in relation to parts of the trawl behind the otter boards is quickly seen.

Occasionally discrimination is so good that even the backstrops and their shadow can be seen (fig 2) and the steel wire bridle can be followed to the dan leno. The scuttle type of dan leno shows up especially clearly when its concave side is facing the scanner.

The net is seen in outline, the floated headline and steel-bobbined bosom of the ground-rope being particularly prominent (figs 3 and 4). These are the parts of the gear which are normally first picked up by the scanner at the extreme operating conditions. Under good conditions on the short range it is sometimes possible to identify the individual headline floats. A rubber-disc groundrope and

Fig 3. Sector scanner representation of front part of bottom trawl showing especially the headline, the groundrope and the otter board eddy trails

Fig 4. Sector scanner representation of the whole of a bottom trawl from otter boards to codend, seen from directly astern. Note noise band originating from groundrope bobbins

bosom, on the bottom along its whole length, is visible but not very conspicuous. Steel bobbins and Lancasters are very conspicuous and generate a great deal of noise which is picked up by the scanner receiver. To give a clearer indication, a few trawl floats have been attached to the codend; when a few baskets of fish such as cod, herring and sprats have collected in the codend it showed up very brightly. Vertical sections of the net can be seen by switching from horizontal to vertical modes when the net is seen in the mid-line of the screen. If the net is being looked at from directly astern then a longitudinal section is obtained and the codend with its attendant turbidity cloud and a dot representing the position of the centre of the headline, can be seen by the practised observer. If the net is being viewed from the side, transverse sections can be obtained at any desired point along its length; from abeam of the headline the arc of this can be seen flanked on each side by an eddy trail from the otter boards (fig 5).

A tickler chain worked between the otter boards, although of only ⅝ in (16 mm) chain, showed up very clearly indeed along its whole length.

Fig 5. Sector scanner representation of transverse section of headline arc of bottom trawl, showing flanking turbid eddy trails from otter board

The noise generated by the trawl parts mentioned above has been a somewhat surprising feature. That trawls are noisy is, of course, well known; it was surprising to be picking up generated noise at 300 kHz. The bands of trawl-generated noise are picked up by the scanner receiver when the transmitter is off. Their presence facilitates location of the trawl when the background noise level is high, but they are a nuisance when they blot out parts of the zone of action of the trawl as they do when the trawl is viewed from astern (fig 4). When the trawl was towed over a mud bottom the noise bands from the otter boards, dan lenos and bobbins were much reduced.

Dimensions of trawls can be measured from the scanner presentation. Any measurement along the range axis will be a true one, but on the width axis (or height if in vertical mode) there will be distortion which must be corrected according to range. Trawl width of opening has been measured by manoeuvring the observing ship to be looking at both otter boards (if it is width between otter boards that is being measured) in the midline of the display on bearing 090° or 270° and simply measuring their difference in range. An appropriate correction for depth has then to be made. Similarly, for wing-end spread, the fairly conspicuous dan lenos were lined up on a bearing at right angles to the course of tow and the range distance between them measured. With the observing ship in this latter position, a switchover from horizontal to vertical mode allowed the headline height to be measured (remembering to correct for range).

It is noticeable that the quality of picture of a trawl as seen by sector-scanner varies appreciably with the type of sea bed being trawled over. On a ridged sandy bottom the quality of picture also varied with the direction of tow. Experience of bottom effects is accumulating and, in itself, is a subject of great interest.

The A.R.L. scanner in RV *Clione* can, under favourable conditions, detect an 8 in (0.2 m) dia trawl float located 18 in (0.5 m) off the sea bed in a depth of about 10 fm (18 m) at a range of 250 yds (229 m). Such a float is roughly equivalent to a cod of length 60–70 cm. Shoals of fish show up very clearly on the scanner and they cast a strong shadow; their shape and movement can be readily studied. What were almost certainly individual fish have been seen. So far the opportunities to try to watch fish in the zone of action of the trawl have been very limited. Where fish shoals have been seen at the same time as the trawl when the scanner was in horizontal mode, a quick change to vertical mode has usually shown them to be much higher in the water than the trawl. On one occasion a small shoal was seen to lift over the trawl headline. One requirement for this work is to be fishing on a ground where fish are very abundant.

CONCLUSIONS

With the present A.R.L. scanner installed in RV *Clione*, details of trawls, both pelagic and bottom fishing, are clearly discernible at ranges of up to 250 yds (229 m) in depths to 30 fm (55 m). At greater ranges and depths—up to 350 yds (320 m) and 60 fm (110 m) respectively—trawls can be located and identified. Within the limits for trawl detail discernment, fish are detectable and, given adequate quantities of fish and proficient scanner operators, the scanner should prove an invaluable means of studying the movements of fish in relation to fishing gear, both on and off the bottom.

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An Evaluation of a Continuous-Transmission, Frequency-Modulated Sonar in Fishery Research

H. S. H. Yuen

Une evaluation du sonar a transmission continue et frequence modulee (CTFM) pour la recherche halieutique

Un sonar à transmission continue et fréquence modulée (CTFM) à été utilisé dans des études effectuées sur le listao (*Katsuwonus pelamis*) par le Laboratoire de biologie du Bureau des pêches commerciales des Etats-Unis à Honolulu, depuis 1966. Les capacités du sonar CTFM sont précisées, en ce qui concerne la portée, la définition et la vitesse d'information. On a attribué l'aisance avec laquelle les cibles sont détectées à sa transmission continue et à sa vitesse d'information élevée. A son début, l'emploi du sonar CTFM a entraîné des problêmes (1) de retards dans la réparation et le réglage provenant d'un personnel inexpérimenté et d'un manque de pièces, et (2) de conversion analogique-digitale de données enregistrées à un rythme très rapide. Le sonar CTFM a été utilisé pour rechercher et suivre le listao. Pendant les opérations de poursuite, des difficultés ont été provoquées par des déplacements brusques et imprévisibles, une faible propriété réfléchissante du son et une tendance de ces poissons à faire des émulsions d'air dans l'eau en surface. Un petit émetteur placé dans un poisson a permis de réussir des opérations de poursuite. Les problèmes englobant les rythmes de détection et l'identification de l'écho pendant les opérations de recherche sont discutés. On résume les informations obtenues sur le comportement du listao grâce à l'emploi du sonar. L'utilisation des sonars CTFM dans l'industrie des pêches est discutée.

Evaluación del sonar de CTFM en la investigación pesquera

En el Laboratorio de Biología que la Oficina de Pesca Comercial de los E.U.A. tiene en Honolulú, se emplea desde 1966 un sonar de transmisión continua y frecuencia modulada (CTFM) en el estudio del listado, *Katsuwonus pelamis*. Se decriben las posibilidades de este aparato en lo relativo al alcance, resolución y velocidad a que suministra la información. La facilidad con que se localizaron los objectivos se atribuyó a su transmisión continua y a la gran rapides con que facilita los datos. Los problemas relacionados con el uso inicial del sonar CTFM fueron: (1) retrasos en las reparaciones y ajustes debidos a la inexperencia del personal y a no disponerse de piezas y (2) convertir a gran velocidad los datos registrados de digital a análogos. El sonar de CTFM se empleó para buscar y seguir el listado. Durante la persecución crearon dificultades sus movimientos repentinos e imprevisibles, lo mal que reflejan los sonidos y su tendencia a crear burbujas de aire mientras están en la superficie. Dio buenos resultados un pequeño transmisor ultrasónico que se había puesto en los ejemplares que se iban a seguir. Se examinan los problemas que plantea la velocidad de localización e identificación de los objetivos durante la búsqueda. Se presenta resumida la información sobre el comportamiento del listado obtenida empleando el sonar. Se discute el empleo de sonar CTFM por la industria pesquera.

In the last decade two interesting developments in underwater acoustic equipment have been applied towards fishery problems. Both of these, the sector-scanning sonar and the continuous-transmission, frequency-modulated (CTFM) sonar, represent departures from conventional pulsed sound techniques to provide high resolution and high rates of information. Although they are quite different from each other, both use narrow beams and rapid scanning to accomplish their objectives. The sector-scanning sonar scans bearing as its first order of scanning while the CTFM sonar scans range as its first order of scanning. Their potential as demonstrated by initial trials and applications in fishery research (Harden Jones and McCartney, 1962; Tucker and Welsby, 1964; Cushing and Harden Jones, 1966; Hester, 1967; and Yuen, 1968) has attracted considerable interest.

A CTFM sonar was purchased by the Bureau of Commercial Fisheries Biological Laboratory, Honolulu, in 1966 to further its studies on tuna behaviour and distribution. The CTFM sonar was chosen over conventional sonars because we believed that the conventional sonars would be inadequate for keeping in contact with the quick moving tunas. The project involving the CTFM sonar set out to do the following: describe the short-term movements, both horizontal and vertical, of the skipjack tuna, *Katsuwonus pelamis*, and investigate the relation between the movements and environmental features; measure such schooling parameters as school size, density, configuration, and stability; describe the migration route of skipjack tuna; and evaluate the effectiveness of the CTFM sonar in locating subsurface tunas.

This evaluation of the CTFM sonar is based on my working experience with it since 1966 and is presented largely from a non-technical viewpoint. The report includes the capabilities and limitations of the CTFM sonar, problems encountered in its use, corrective measures, results of current work and a discussion of its potential use in the fishing industry.

CAPABILITIES AND LIMITATIONS

The distance an object can be detected by sonar depends on how well the object reflects the sonar signals. The CTFM sonar has a range of 1600 m for objects with echoes of sufficient strength. The detection ranges of various species (Table 1) are reproduced from Yuen, 1967.

TABLE 1. MAXIMUM RANGES AT WHICH VARIOUS ANIMAL TARGETS WERE OBSERVED ON THE CRT DISPLAY

Mode	*Target*	*Maximum range (m)*
Search	Dead skipjack tuna (65 to 75 cm fork length)	
	One	235
	Two (one above other, 30 cm apart)	340
	Three (one above other, 35 cm apart)	380
	Surface skipjack tuna schools (1 to 11 kg)[1]	650
	School of yellowfin tuna (*Thunnus albacares*) (18 kg)[1]	545
	Subsurface fish (unidentified)	389
	Whitetip shark (*Carcharhinus longimanus*)[1]	340
	Billfish (Istiophoridae)[1]	280
	Porpoise[2] (probably *Stenella attenuata* or *Steno bredanensis*)	
	One	ca. 400
	Group	800
Classify	Dead skipjack tuna (65 to 75 cm fork length)	
	One	130
	Two (one above other, 30 cm apart)	130
	Three (one above other, 35 cm apart)	130

[1] Identified visually at the sea surface.
[2] Identified from the display of their own sounds on the CRT.

Although skipjack tuna were detected up to 650 m, the limit of detection for this species was usually 300 to 400 m.

The CTFM sonar has a high resolution mode called the classify mode. In this mode the sonar has a range resolution of 0.0019 times the target distance and a bearing resolution of 0.01 times the target distance. This means that if there are two targets one behind the other relative to the sonar transducer at a distance of 100 m, they would need to be at least 19 cm apart to be recognizable as two targets. If the two fish were at different bearings but at the same range they would need to be 1 m apart at a distance of 100 m to be distinguishable as two targets.

The sonar can be operated at a ship's speed of 18 km/h (10 kn). Beyond 11 km/h (6 kn), however, noise level begins to interfere with effective operations. At 15 km/h (8 kn) virtually no useful information can be obtained.

The outstanding feature of the CTFM sonar is its continuous transmission of acoustic energy. As illustrated in fig 1, the projected signal is frequency modulated in a sawtooth pattern. Subtracting the frequency of the outgoing signal from that of the echo results in a difference

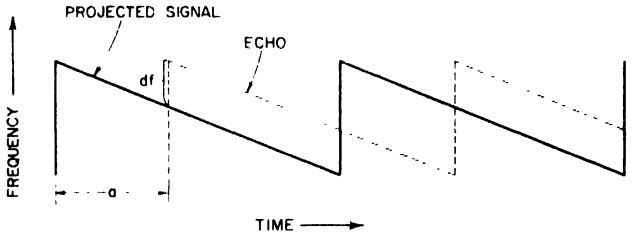

Fig 1. Pattern of frequency modulated signal and echo. a = loss time, df = difference frequency

frequency labelled *df* in fig 1. The magnitude of the difference frequency is proportional to the time lapse between the transmission and the return of the echo. The time lapse, labelled *a* in fig 1, is in turn proportional to the distance of the reflecting object so that the difference frequency is also proportional to this distance. Information on the target is received throughout the sawtooth period after the time lapse *a*. In a conventional pulsed sonar the information is only available for the length of the pulse.

Since no information is received during the time lapse *a*, this period is called the *loss time*. There is a method to recover the information during the loss time but it is not incorporated in our sonar.

Loss time increases as target distance increases so that the length of time that information is received varies inversely with target distance. Information time can be lengthened proportionately by lengthening the period of the sawtooth. The gain in information time by this method, however, is made at the expense of range resolution.

The difference frequency is processed through a frequency analyzer of 100 bandpass filters. The outputs of the filters are read sequentially every 7 msec. The 7 msec. can be divided into a reading time of 5 msec. and a pause of 2 msec. A high information rate is the result of this rapid reading rate.

How do the attributes of continuous transmission and high information rate contribute to the performance of the sonar in locating a target? The question can best be answered by reviewing an experiment. A target was placed in the water. Its depth was changed at various times from 10 m to 80 m below the surface. The ship repeatedly went past the target at various distances at a speed of 7.5 km/h (4 kn). The sonar operators were instructed to find the target with no prior knowledge about its position. Furthermore, the operations of the sonar was restricted to a standard scanning pattern for searching. The target was detected 23 out of the 24 times the ship passed within sonar range of the target. In my opinion, the high detection rate was possible only because of the features of rapid information and continuous transmission of the sonar.

The high certainty of detecting objects has provided an unexpected benefit. The sonar has been used successfully in locating submerged instruments which had lost their surface markers.

PROBLEMS

Some problems were encountered in the use of the CTFM sonar. Some were solved; others corrected themselves with time; others still remain. Corrective measures taken are described.

One early problem was the time spent on repairs and adjustments. Because the equipment was new, maintenance personnel were unfamiliar with it. As a result repairs and adjustments, even minor ones, required much time. As personnel gained experience, the seriousness of the problem diminished.

The sonar has many specialized components whose replacements are difficult to obtain. Some parts are not available in Hawaii. Others are constructed as they are ordered; these are not readily available anywhere. Delays of various durations have resulted when parts were not on hand. In the most extreme case a high precision potentiometer required 18 months to obtain. During that time the classify mode was out of order. Delays in repairs have been considerably reduced but not entirely eliminated by storing an extensive supply of spare parts, particularly critical ones.

The data collected during sonar operations were recorded on a 14-channel, analog, magnetic tape recorder. To make the data acceptable for processing by a computer, conversion from analog to digital was necessary. A problem was encountered in digitizing of the sets of the 100 sequential readings of the frequency analyzer. It was necessary to signal the analog-to-digital converter to start precisely at the beginning of each set. Failure to do so would have caused the sets to become mixed, which would have rendered the data meaningless. Efforts at instructing the computer directing the conversions to detect the exact starting time and then to signal the converter failed because there was insufficient time between the detection process and the signalling process. Conversions were successfully made when an electronic device was added to the system to suppress signals

activating the converter unless they began at the same time as the sets of reading from the frequency analyzer.

The operations of the CTFM sonar were of two types. It was used primarily to track skipjack tuna which had been located and identified visually. Tracking operations were for the purpose of obtaining behaviour observations. The sonar was used secondarily to find subsurface schools of skipjack tuna. Searching and tracking operations were both hampered by the limited range at which skipjack could be detected. Within the area of the Hawaiian skipjack tuna fishery, where most of the work with the sonar has been done, surface schools of this species have been sighted at a rate of approximately one per 300 km^2. Even if one supposes that for every school at the surface there is another beneath the surface, a sonar scanning a radius of 400 m on a ship travelling at 10 km/h would have an expected detection rate of one school per 10 hours. This result is based on the assumption that the skipjack schools move randomly at a speed of 5 km/h.

The effective range of 300 to 400 m for skipjack tuna was found to be inadequate during tracking operations. The fish with their sudden and unpredictable movements moved out of range before the ship could be manoeuvred in response.

A difficult problem in searching with a sonar is target identification. At present the more experienced sonar operators believe that they can identify echoes of skipjack tuna and sharks. The identification criteria, however, are subjective and therefore difficult to describe. An attempt is being made to formulate objective criteria of identification. To do this, sonar records of positively identified species will be processed through a computer for analyses of strength, movement, and spacing of echoes with respect to time. Since the information from the sonar has been recorded in cycles of 7 msec. very detailed analyses will result in a practical method of identifying species.

Skipjack tuna at the surface presented special problems which made tracking them difficult. The strength of echoes of skipjack tuna, as with most fishes, depends upon the orientation of the fish to the sonar. Echoes are strongest with a lateral aspect of the fish and weakest with the head and tail aspects. Dorsal and ventral aspects result in echoes which are almost as strong as those from a lateral aspect. Echoes from fish below the sonar, therefore, are consistently fairly strong because the fish present a dorsal aspect regardless of the direction they are swimming. Echoes from surface fish, on the other hand, vary widely in strength as the fish change their directions. Furthermore, when one is tracking a fish one is likely, most of the time, to be behind the fish, where the echoes are the weakest.

Another problem with skipjack tuna at the surface is that they have a tendency to break through the surface and thus introduce masses of air bubbles into the water. Unwary sonar operators have often concentrated on the echoes from these air bubbles while the fish moved away. A tracking technique with some degree of success was to have the operator constantly scan below the fish in order to detect them when they left the surface. Of course, the procedure did not work if the fish moved out of range before leaving the surface.

In the summer of 1969 a major advance in tracking was made. A skipjack tuna that had been induced to swallow a small 50 kHz transmitter was followed with the sonar for six days; another for 12 hours. The transmitters could be detected up to 2.5 km. The transmitters which were used had a life of 10 days but transmitters lasting 60 days are now available.

RESULTS AND COMMENTS

The CTFM sonar has been used by the Biological Laboratory, Honolulu, primarily as a tracking device to study the behaviour of skipjack tuna. Results thus far indicate that: (1) skipjack tuna will go as deep as 200 m; (2) larger skipjack tuna tend to go deeper than smaller ones; (3) small skipjack tuna remain close to the surface at night but make many excursions away from the surface during the day; (4) the speeds of their vertical movements average 0.3 m/s and can be as high as 3.3 m/s.

Behaviour information of the type mentioned is useful in the design of fishing gear and strategy and thus contributes to the fishing industry from a long-range point of view. When a fisherman considers installing a sonar on his boat, however, he is interested in obtaining information for immediate use. Moreover, he is primarily interested in an inexpensive method of efficiently locating fish. Other information is of secondary importance. For the CTFM sonar to be widely accepted in the fishing industry, therefore, it must be inexpensive and its effectiveness as a fish finder needs to be demonstrated.

The sonar model here discussed costs US $210,000. It is much more complex than would be required for fish finding purposes.

The low detection rate for skipjack tuna in the Hawaiian fishery does not mean the CTFM sonar will not be useful as a fish finder in other fisheries. The detection rate for a given species depends on species-related parameters. In most cases, the rate can be expected to be higher than that for skipjack tuna. Because of the importance of the swim bladder in reflecting acoustic energy (Cushing and Richardson, 1955; and Harden Jones and Pearce, 1958) echoes from skipjack tuna, which do not have swim bladders, are weaker than those from many species which do have swim bladders. Species which are more concentrated in their distribution than the apparently widely separated schools of skipjack tuna will have a higher detection rate. The probability of detection increases with an increase in the difference between the swimming speed of the fish and the searching speed of the ship. In general, slower swimming fish will be more likely to be encountered than faster swimming fish such as the skipjack tuna. Whether detection rates will be high enough to justify the cost of a CTFM sonar will have to be determined individually for each fishery.

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Selecting Acoustic Equipment to Suit Particular Fishing Conditions

Simonsen Radio A.S.

Choix d'un equipement acoustique convenant a des conditions de pêche specifiques

Lorsqu'on choisit du matériel acoustique en vue d'opérations spécifiques de détection du poisson, il est très important d'aborder les problèmes considérés d'une manière mèthodique. On trouve sur le marché une grande variété d'échos-sondeurs, de sonars, ainsi que de chaluts montés ou d'équipement de trait. L'utilisateur doit donc évaluer soigneusement tous les éléments en cause pour être certain d'obtenir les meilleurs résultats. A cet égard, les bases de travail de l'utilisateur sont importantes, à la fois du point de vue personnel et sous l'angle du milieu. En effet, la structure économique de son entreprise en dépend. Ses besoins sont déterminés par l'ampleur de ses activités halieutiques, présentes et à venir. Pour être sûr de faire un investissement profitable, il devra, avant de prendre sa décision, étudier soigneusement les spécifications de l'équipement disponible sur le marché, sans oublier de considérer les prix, les conditions de paiement, les instructions pour l'installation du matériel, le service après vente et son coût.

Selección de equipo de sondeo acustico de acuerdo con las condiciones especificas de la pesca

A la hora de escoger el equipo de sondeo acustico para la localización de peces es muy importante abordar metódicamente los problemas que se plantean. Existe en el mercado gran variedad de ecosondas, aparatos de sonar y equipo para montar en la red o remolear. El usuario, pues, debe evaluar cuidadosamente todos los elementos, para estar seguro de lograr los mejores resultados. A este respecto, es importante su situación personal y ambiental porque es la que delimita el marco económico de su actividad. Las necesidades están determinadas por sus actividades pesqueras, actuales o previstas. Para garantizar una inversión segura y prove chosa, el usuario debe estudiar cuidadosamente, antes de decidirse, las caracteristícas del equipo disponible en el mercado, sin olvidar los precios, las condiciones de pago, las instrucciones de montaje, los servicios de manutención y los probables costos de dichos servicios.

DURING the last decades there has been an explosive expansion in the field of acoustic equipment for fish-finding purposes. A number of manufacturers now offer a comprehensive and varied range of acoustic fish-finding equipment to those faced with the problem to select such equipment for a particular vessel and for particular fishing conditions.

This decision is either taken by the owner or the skipper, or—if the vessel belongs to a fishing company owning a number of vessels—by someone on company staff.

A number of factors must be carefully checked before decision is made. This paper, therefore, endeavours to expose a pattern for systematic evaluation of the elements which must be considered when selecting acoustic equipment to suit particular fishing conditions.

Background and requirements

There is an enormous gap between the fisherman who is fishing alone in his canoe, and the skipper of a modern well-equipped factory trawler. Consequently, the background of the users vary widely. Common for all users of fish-finding equipment is the goal to get the biggest catch with the lowest expenses in the shortest possible time.

How a user achieves this goal is largely dependent on his own general attitude towards economic and social success, and on his ability to exploit the available resources of knowledge, finance and existing or potential markets for his products.

His success also depends on his own general attitude towards instrumentation. The user's equipment is only of value to the extent he is willing and able to learn its proper use. He must adapt himself to the equipment and put to use his ability to improvise.

Some of the more important elements of the user's background, in this connection, may be defined as his:

Ingenuity and adaptability
Willingness to gamble
Educational level
Willingness to learn
General attitude towards economic and social success
Economic status
Opportunity of profit

A correct grouping of the user's requirements is helpful when he is going to select acoustic equipment in relation to his actual fishing activities and his future plans. This approach is better than starting off by studying the specifications of available equipment, as such a procedure might easily mask his real requirements.

The spectrum of fishing activities is huge, varying from simple tin bait fishing through longline fishing seine netting to trawling and purse seining. The actual or planned fishing activities must therefore be clearly defined. These activities should be considered in connection with the species of fish caught, their behaviour, and the type and size of the vessel and its present or planned fishing gear.

One must bear in mind that all types of acoustic equipment require electric power. It is therefore important that sufficient electric power of correct type is available or can be made available for the equipment selected.

The price of the equipment is often a limiting factor. Buying a certain piece of equipment must always, in addition to filling a specific demand or purpose, be an economically sound proposition. It must be stressed that the list price of a piece of equipment should only be judged in conjunction with installation costs, available service facilities, and expected maintenance costs. It is obvious that low maintenance costs and long, dependable service life may well justify a higher initial cost.

Requirements of the user are influenced by:

The species of fish and the fishing methods
The vessel and its possibilities
The type of fishing gear—how and where it is used
The economic framework of his fishing activities
The price of the equipment
Installation costs
Service facilities available and maintenance costs
Dependability of the equipment
Instruction facilities

The customer should check these points carefully before committing himself.

Manufacturer's offer

The laws of the physics of sound in the sea are well known and have been extensively covered in current literature. Manufacturers are fully aware of these laws, as evidenced by their products.

It is necessary that the user—at a level suitable for practical fishing—be familiar with these laws, in order to get the full benefit of his equipment (see bibliographic references).

The following matter shows how the manufacturer's offer should be studied in detail to get a clear picture of the equipment available, its specifications, to see if the manufacturer offers help with the installation planning, and if he supplies adequate instruction and instruction manuals. Also important are dependability and quality of the equipment, and what arrangements the manufacturer has made for future service and maintenance.

The installation of acoustic equipment must be undertaken with utmost care. Here the customer must rely on the manufacturer's experience. The customer should also comply with recommendations of the manufacturer regarding noise suppression (keeping acoustic and electrical noise at a low level) and should follow directions regarding installation (proper placement) and tests for ensuring best results. This is due to the fact that the vessel itself and the shape and condition of its various parts may have a serious effect on the efficiency of the acoustic equipment. In this respect the manufacturer's experience is extremely important for the performance of the equipment.

Full benefit of acoustic equipment is dependent on combined theoretical and practical instruction. Apart from instruction in general, the manufacturer should provide adequate training on the actual equipment installed. Instruction may take place when the installation tests and measurements are finished. By keeping his servicemen informed about the operational aspects of the equipment, the manufacturer enables his servicemen to intelligently help the user in solving his operational problems, for example interpretation of echo recordings.

Efficient and quick service is all-important. The service facilities must therefore be good, with an ample supply of spares available at short notice, and at the user's ports of call. The servicemen must be continually kept up to date with the latest information about the equipment.

The price of equipment is naturally decisive. When comparing prices, however, it must be borne in mind that price policy may vary from one manufacturer to another. It is obvious that if assistance with installation planning, installation supervision and instruction are included, these services are really quite valuable, and may, in fact, mean the difference between a successful installation and a problem-filled one. It is equally obvious that if lack of—or only poor service facilities are available, even a low price is a poor bargain.

THE FINAL CHOICE

In order to evaluate the manufacturer's products, the customer must therefore consider:

The product specifications
The power requirements
Installation instructions
The price and what it includes
Operating instructions
Ease of operation
The service facilities and service costs
Service and operational manuals

If the prospective buyer of acoustic fish-finding equipment starts off by carefully studying the points mentioned, the chances are that he ends up with what may not be the cheapest equipment, but the right equipment for his particular fishery.

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Training in the Use of Echo Sounder and Sonar

Simonsen Radio A.S.

Formation à l'emploi de l'écho-sondeur et du sonar

En Norvège, la formation des pêcheurs à l'emploi des appareils de détection du poisson est généralement donnée par le constructeur local, le Syndicat des pêcheurs et le Gouvernement, SIMRAD, le constructeur norvégien, a organisé un certain nombre de cours, soit seul, soit en coopération avec la Direction des pêches et le Syndicat des pêcheurs. La Direction des pêches a mis sur pied des cours mobiles sur l'emploi de l'écho-sondeur et de sonar, qui ont eu lieu presque chaque année depuis 1959. L'Ecole des pêcheurs norvégiens a inclus dans son programme destiné aux futurs patrons de pêche des cours de formation à l'emploi de l'écho-sondeur et du sonar. Le Syndicat des pêcheurs norvégiens en fait autant sur le plan local. Des étudiants et des spécialistes d'outre-mer, dont certains sont parrainés par la FAO, viennent en Norvège s'initier à l'utilisation des instruments de détection du poisson. Pour accroître l'efficacité des cours, il conviendrait d'utiliser des simulateurs reproduisant les conditions réelles dans lesquelles on emploie des écho-sondeurs et des sonars à la pêche. Il est possible de se procurer des simulateurs pour l'écho-sondage. Par contre, ne dispose pas encore de simulateurs de sonar répondant aux exigences actuelles.

Capacitación en el empleo de la ecosonda y el sonar

En Noruega, la capacitación de los pescadores en el empleo del equipo para localización de peces ha corrido a cargo, de ordinario, del fabricante mismo, de la Unión de Pescadores y del Gobierno. La empresa noruega, SIMRAD, que fabrica dicho equipo, ha organizado diversos cursos por su cuenta y en colaboración con la Dirección de Pesca y con la Unión de Pescadores. La Dirección de Pesca ha organizado casi todos los años, desde 1959, cursos ambulantes sobre ecosonda y sonar. En el programa de formación de patrones de pesca de la Escuela Noruega de Pescadores figura la capacitación en el empleo de ecosonda y sonar. La Unión Noruega de Pescadores organiza cursos sobre el empleo de ecosonda y sonar en las secciones locales. Estudiantes y científicos extranjeros, algunos de ellos subvencionados por la FAO, visitan Norguega para iniciarse y capacitarse en el empleo de los instrumentos de localización de peces. Para aumentar la eficacia de los cursos deben emplearse modelos que reproduzcan las condiciones reales en que se emplean las ecosondas y el sonar. Se dispone ya de modelos para el sondeo acústico, pero no existen aún de sonar que satisfagan todas las necesidades.

FROM a modest beginning after World War II the echo sounder and sonar instruments have developed to be an important part of fish finding equipment in practical fishing all over the world (figs 1 and 2). The very first echo sounders were of simple construction, easy to operate, with few controls and setting possibilities. But it was not before fishermen overcame their belief in the fallacy "electricity in water scares fish" that the echo sounder became an inevitable instrument in navigation as well as practical fishing.

Use of sonar for fishing developed from experiments carried out in 1946 with military sonar equipment. The possiblities of searching an area around a vessel gave the fishermen a better tool for long range fish detection, resulting in good catches and more profit. Experience has, however, clearly revealed the necessity for intense training in operating this equipment.

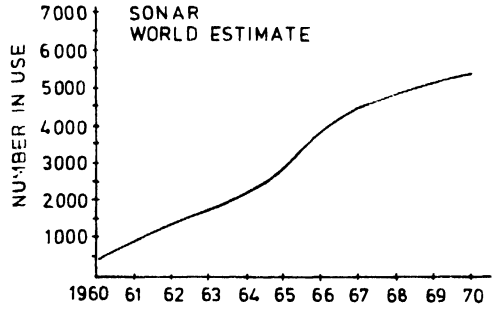

Fig 1

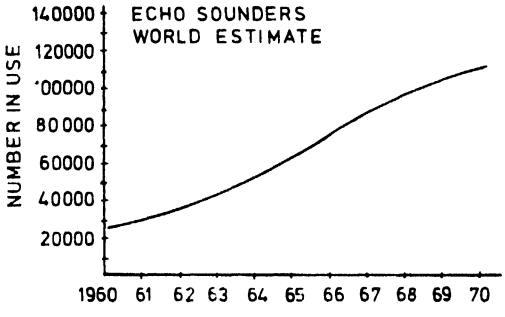

Fig 2

Need for instruction

In the development of echo sounders and sonars the manufacturer always attaches importance to simple operation. Elementary echo sounders, primarily designed for depth finding, are usually quite simple to operate. However, a steadily increasing demand for instruments of high performance and versatility has led to the production of equipment of high complexity. Operation of such equipment necessitates trained personnel (see fig 3). As far as commercial sonar is concerned, basic training will always be a necessity for profitable operation.

The basic working principles of the echo sounder are simple (see fig 4). The relationship between the actual conditions within the vertical sound beam and recorded signals will also be easily understood.

Echo sounders may be divided into three groups according to complexity:

Simple echo sounders with only few controls, such as range, amplification and illumination controls (fig 3). Certain echo sounders for navigational purposes, and echo sounders for small fishing craft belong to this group. Such sounders may have a flash indicator or a graphical recorder, or a combination of both. These sounders necessitate no special instruction. Information is normally gained by following the instructions given in the Operator's Manual.

Echo sounders to suit different fisheries and conditions (fig 3). Because of the increased number of controls and setting possiblities these echo sounders are more versatile and more complicated in operation. Proper operation of this equipment is not obtainable by reading the operating instructions only, but through special instruction and practical experience.

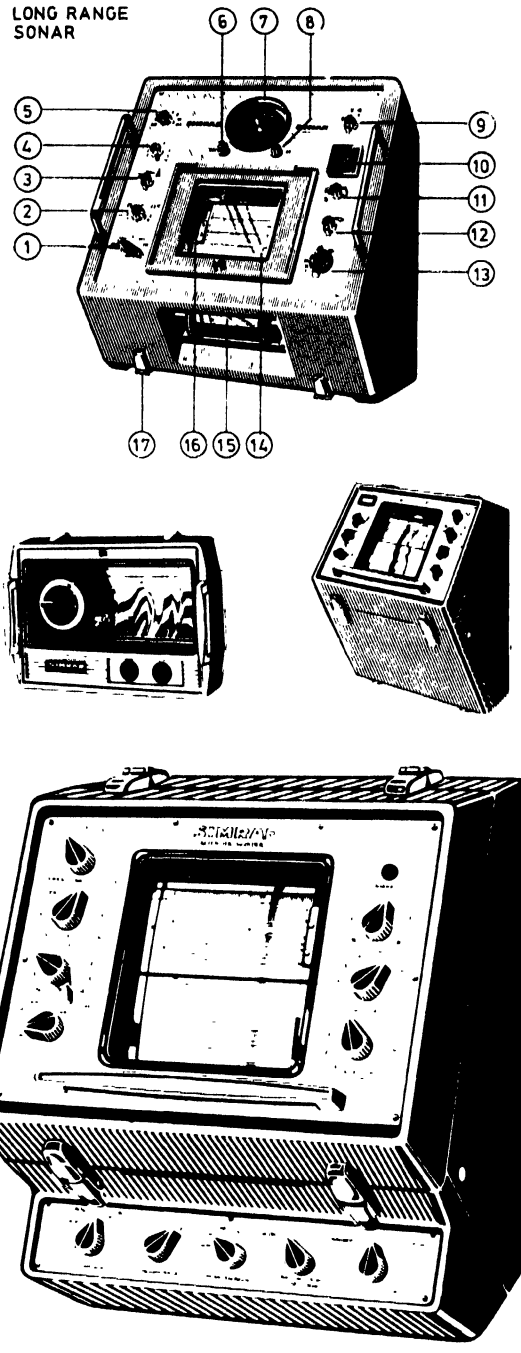

Fig 3. Top: Long range sonar. Middle left: small echo sounder recorder. Middle right: a powerful and versatile fishing echo sounder recorder. Bottom: a sophisticated research echo sounder recorder

Scientific Sounder systems (fig 3). These systems usually include special displays, such as precision depth recorder (PDR) and cathode ray tube (CRT) displays, and instrumentation for quantitative measurements. These are instruments of high complexity. The full use of equipment of this kind requires extensive training.

Sonar instruction

In general, operating a sonar is more difficult than operating echo sounders. The sonar operator has to develop a sense for geometric mapping of the actual fishing situation (see fig 5). The operator must, in his own imagination, construct a three-dimensional picture of the area around the vessel by reading the distance on the recorder, the bearing on the bearing indicator and estimating the target depth by means of the tilt indicator. Even a small hand operated sonar (fig 6), simple to operate and with few setting possibilities lays claim to the operator's capability.

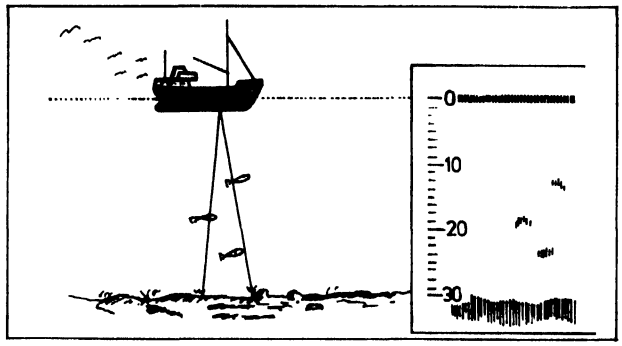

Fig 4. Scheme of echo sounding and recording

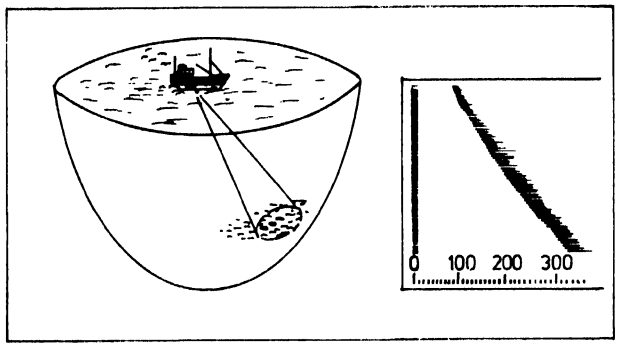

Fig 5. Scheme of sonar operation and recording

A fully automatic sonar for long range detection (fig 6), with its indicators, controls and combinations, can only be fully utilized by an experienced and well-trained operator.

The ability of the sonar operator to construct a correct picture of the situation, and to use it as a basis for his actions, may mean a good catch—or no catch. Therefore tactical exercises should be an important part of any sonar training programme.

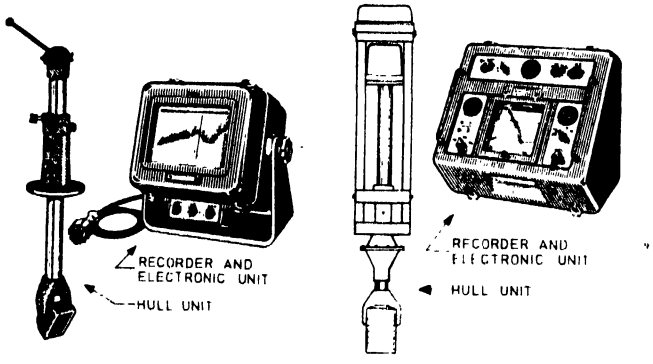

Fig 6. Left: small hand operated sonar
Right: automatic long range sonar

Most sonar training courses provide practical training in operating the instruments at sea. Sea training, however, is both time consuming and expensive. Of advantage, therefore, would be extensive training with sonar simulators.

Training should also provide a certain knowledge of the physical conditions in the sea and the influence of these on the instrument's performance.

TRAINING AND EDUCATION

In Norway, a fisherman can obtain training and education in the use of acoustic fish-finding equipment from:

- The manufacturer of the equipment
- Courses arranged by The Norwegian Directorate of Fisheries
- The Norwegian Fisheries Schools
- Courses arranged by The Norwegian Fishermen's Union

From the time of very first equipment the user has called for instruction in how to operate his intrument for maximum utilization.

Today's users have, to a certain extent, the benefit of training provided by the manufacturers. This normally follows the technical tests and measurements which terminate the installation. Circumstances—usually lack of time—very often prevent thorough instruction.

Some of the technical courses arranged by Simrad contain subjects covering: the practical utilization of echo sounders and sonars, physics of the sea, interpretation of echograms, etc.

The curve in fig 7 shows the number of trainees participating in those courses.

Since 1959, The Norwegian Directorate of Fisheries has in cooperation with Simonsen Radio A.S., arranged ambulatory sonar/echo sounder courses for fishermen (see fig 8). The general plan for them was developed by The Institute of Marine Research in Bergen and Simonsen Radio A.S.

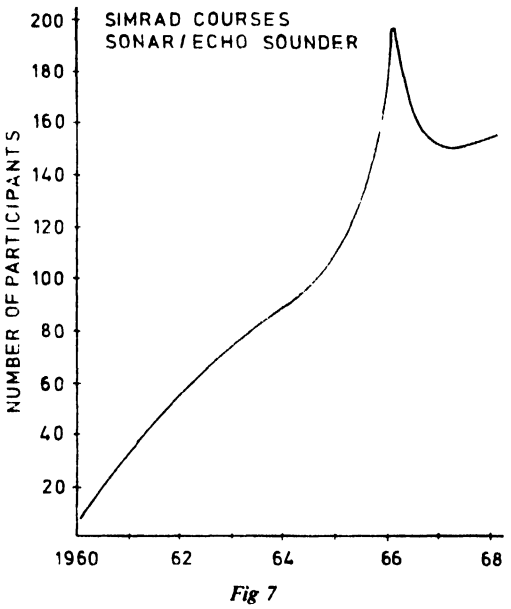

Fig 7

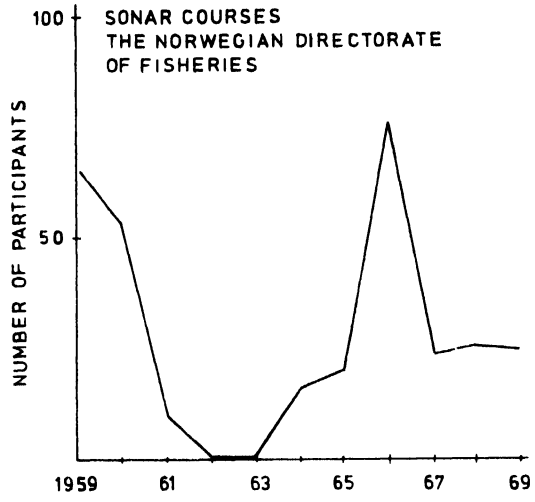

Fig 8

Mr. G. Vestnes outlined this training programme at the Second FAO World Fishing Gear Congress, London 1963, in his paper: "Sonar Instruction Courses for Fishermen" (Vestnes, 1964).

The participants of the courses gather in one of the Norwegian fishing ports for a one to two week period. The aim of this course is to give the participants training in the practical use of fish finding equipment under varying circumstances. Theoretical knowledge of working principles and tactical use of the equipment is also provided.

TABLE 1. MAIN SUBJECTS AND TIME ALLOCATION

	Classification	
	Theoretical periods	Practical periods
1 Introduction to fish finding instruments, maintenance	2	2
2 Sound velocity. Refraction of sound in the sea	3	
3 The instrument's performance dependent on location of equipment	2	
4 Interpretation of recordings, the principles	6	
5 Dry-training, operating the actual instrument		2
6 Tactical application of fish finding instruments	4	
7 Practical training with echo-sounder and sonar at sea		21
	17	25

Total 42 periods (each at 45 minutes).

Figure 9 shows how the course programmes have developed according to experience gained from 1959 to 1969.

Practical training occupies a larger part of the present courses when compared to initial courses. However, the reduction of theoretical training in order to stay within given time limits may be questioned. An extension of the course duration is, from the fishermen's viewpoint, undesirable.

Thus it is essential to keep the course within present time limits, still maintaining a high standard of efficiency.

The five Norwegian Fisheries Schools, also under the administration of The Directorate of Fisheries, have an

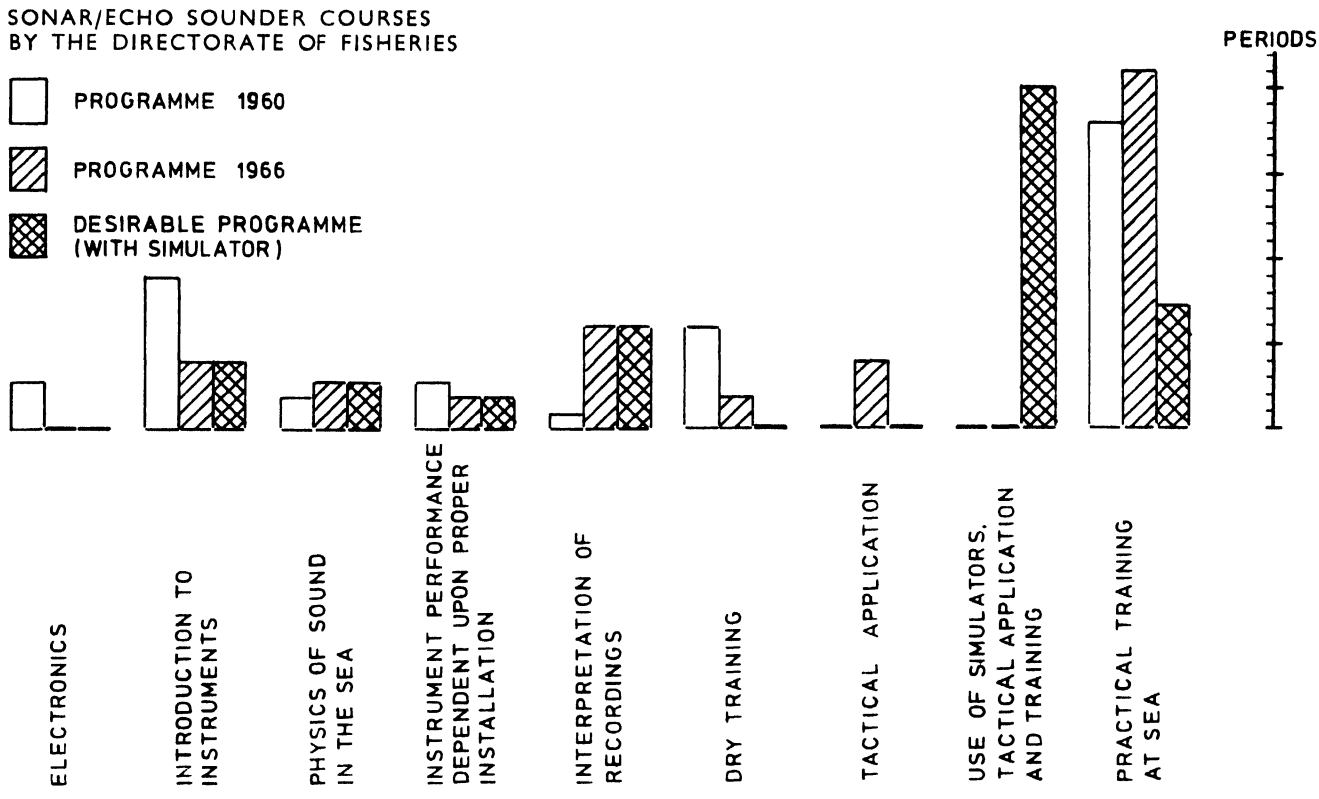

Fig 9

echo sounder/sonar training programme included in their ten and a half months Fishery Skipper Course and supplementary courses. (Myklebust, 1968).

In addition to practical training, 20 periods of theoretical teaching are spent on this subject.

These schools, during 1970, will be equipped with echo sounder simulators.

The local chapters of The Norwegian Fishermen's Union, from time to time, arrange echo sounder/sonar training courses.

Principally, the different programmes for sonar/echo sounder teaching closely follow the subjects in the programme of the Directorate of Fisheries.

Training of instructors, consultants and students

Today's sophisticated acoustic intruments for scientific use call for comprehensive training of marine students and scientists.

At present regular training in this field is not available, although it is very desirable.

Students and scientists, some sponsored by FAO, visit manufacturers of acoustic instruments for instrument information and training. This way of bringing marine scientists in contact with the engineering teams at the development laboratories often leads to mutual cooperation which accelerates the development of suitable equipment.

As far as training is concerned, however, it will always be a great problem for the manufacturer to provide suitable programmed theoretical and practical training. Particularly when individuals appear for information and training, one is prevented from giving adequate practical training, due to lack of qualified instructors available and a tight schedule of our own training vessel. This problem is usually increased as visitors from abroad often arrive on short notice.

From the manufacturers' and also from the users' point of view, there should be available special courses for different training needs, having programmes which develop in pace with the actual demand.

IDEAS FOR PROSPECTIVE COURSES

Classroom and laboratory lectures are effective in engaging all participants. Sea training, on the contrary, will invariably be time consuming as only two to three trainees can be engaged at a time, while the majority must stand idly by. This problem with sea training explains why so much time must be spent on this subject.

Therefore, in order to offer better training in future, echo sounder and sonar simulators should be used extensively to reduce time spent on actual sea training.

Use of simulators for education and training is accepted in many fields today. The reason is mainly that the expenses involved and the value of the material to be operated are often so great that use of real equipment for training purposes would be prohibitive.

In addition to simulators for training, there are simulators for studying the influence of one or more elements on a complete system.

The initial cost and running expenses of a modern fishing vessel are high. It is very seldom that time and money have been earmarked for training of the sonar operator, whose abilities may decisively contribute to the vessel's success.

By means of a sonar simulator (fig 10) it is possible to train operators and furthermore give the candidates at a low cost the sonar drill which would otherwise have required long and expensive training on the fishing grounds.

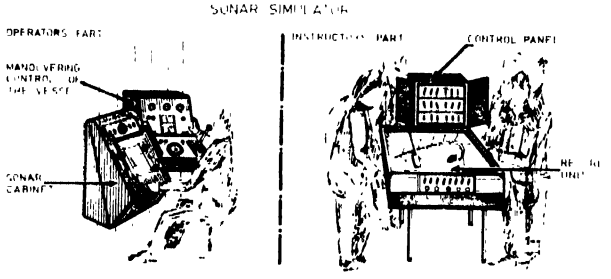

Fig 10

A simulator for echo sounder recording is already available and has been used with success. This is a rack installation, with a SIMRAD echo sounder EK and Tandberg Tape Recorder Model 11 with synchronizer unit.

Sonar simulators meeting actual requirements are not at present available. In the future, a greater part of the practical training could be performed on simulators, thus reducing expenses in actual sea training.

CONCLUSION

The world's fishing fleets are constantly increasing in number and size. The fish finding instruments on board will be more and more advanced in presentation of information, and also more complicated in operation.

This trend is fine, as long as the fish finding equipment is properly utilized. This is not the case, however. The degree and quality of education and training are not keeping pace with the increasing complexity and number of fish finding instruments.

The fact is that there is a gap . . . an education gap, which is just now beginning to widen. This is an alarming tendency and can only be combated by increasing the amount and quality of training activities.

A "gap" between increasing technology and degree of education does not adequately describe the absolute necessity for immediate action. **Action to stop the widening of the gap must begin now.** Right now, technology has the head start. Education must catch up. Delay means that even more funds and time will be wasted in **trying to catch up instead of pulling ahead.**

Shall we wait . . . using money and time only on trying to catch up? Or, shall we use our know-how and resources and put education in the lead?

Remember, the success of all modern fish finding equipment always depends upon the man behind the apparatus . . .

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Shore-based Training of Trawler Officers

R. Bennett

Formation à terre des officiers de chalutier

Parallèllement aux progrès techniques rapides apportés aux bateaux, aux engins et aux méthodes de pêche, il existe un besoin croissant de formation des officiers et des patrons, l'apprentissage traditionnel en cours d'emploi n'étant plus jugé adéquat. En outre, on estime qu'indépendamment des cours, la formation à terre doit tirer pleinement parti des auxiliaires audio-visuels modernes. Parmi une première série d'auxiliaires de l'enseignement, on a construit un modèle de la timonerie d'un gros chalutier britannique, doté d'instruments et relié à un enregistreur sur bande à canaux multiples. Ce système d'enseignement est surtout limité par l'impossibilité où se trouve l'élève d'agir sur le cours des évènements. On envisage donc de produire un nouveau type de simulateur pourvu d'un ordinateur, qui donnerait la possibilité de reproduire une grande variété de situations de pêche. Il s'agira là d'une réalisation très coûteuse. Comme solution de rechange, on peut encore envisager de donner une formation par simulation de situations de pêche au moyen de fiches servant à la présentation des données et de schémas d'exécution.

Capacitación en tierra de oficiales de arrastreros

Los rápidos progresos técnicos logrados en los barcos, los equipos y los métodos de pesca hacen cada día más necesario dar a la oficialidad y a los patrones de pesqueros más capacitación que la tradicional adquiréda a bordo. Al mismo tiempo, es evidente que en la capacitación en tierra hay que aprovechar al máximo, además de las lecciones, las ayudas didácticas audiovisuales modernas. La primera generación de estos medios didácticos audiovisuales está representada por la reproducción del puente de mando de un gran arrastrero por popa británico, con los instrumentos conectados a un magnetófono de various canales. La principal limitación de este sistema de enseñanza es la imposibilidad en que se encuentra el alumno de influir en el curso de los acontecimientos. Por esa razón, se intenta ahora pasar a la segunda generación de medios audiovisuales, empleando un ordenador que permita simular una vasta gama de situaciones de pesca, pero el aparato será muy caro. Otra posibilidad sería simular las condiciones de pesca mediante tarjetas perforadas que reprodujeran la acción y el curso de la misma.

ASSOCIATED with expansion of world fisheries in recent decades, and frequently responsible for it, there has been a parallel technological development in design of fishing vessels, in fish finding apparatus and other instrumentation, in fishing gear, deck machinery and equipment for the handling and processing the catch.

But, in many fisheries, there is a growing awareness of an ever-increasing gap between the development of new equipment and techniques on one hand, and the training of fishermen, and particularly the officers, on the other. In many cases investment in advanced equipment is largely wasted because of the inability of the captains of the vessels to take full advantage of such equipment. Advanced fish detection apparatus is a case in point. Similarly, many problems associated with poor quality of catch are associated with inadequate training and education of the officers and crews.

Of course, in nearly every country fishing vessel officers are given basic training in navigation, seamanship, radar and radio, etc. In some countries such training is extremely thorough; in others much less than adequate. This training usually covers only the basic mechanics of transit and handling the vessel and its equipment safely while on the grounds. With very few exceptions there is no formal training in the officers' professional roles as fishermen and managers of fishing vessels.

As a general rule the men have to learn their profession by working their way up through the ranks from deck crew to mate. This system suffers from several disadvantages. The amount learnt by a junior officer depends largely upon the ability and willingness of the captain to impart his knowledge—some captains may be considerably less than willing. Even when the captain is willing, the manning system and hours of work may severely limit instruction and the overall result is that training by this system can only be described as haphazard.

Yet, in a large proportion of fisheries, the performance of the vessel in terms of its productivity, depends to a large extent upon the calibre of the captain. There are thus large potential gains to be made if training systems could improve the standard of performance of average and below average men.

GENERAL CONSIDERATIONS

About two years ago the White Fish Authority considered the requirements for training of trawler officers in the detection and capture of fish. It began to appear that the main reason for the difference in performance between individual captains, even when equipped with identical vessels, lay in the ability to master complex decision-making processes. Decisions have to be made as to where to start fishing, when to shift grounds and also when to haul (when to shift depth, to alter trawl rigging, change trawls, etc.). The information available to the captain for making these decisions comes from a variety of sources—other vessels, echo sounder signals, weather reports, etc., together with the man's own background of experience and knowledge. The problem is further complicated by the highly competitive nature of the market, so that it is hardly surprising it can be continuously mastered only by men of exceptional ability.

Of course, many other aspects of the captain's work are extremely important, such as the need to be aware of all factors affecting the quality of the catch, and these would have to be included in any proposed training system. Nevertheless, it was felt that the central feature of such systems must be the training in the decision-making processes.

It was also felt that there is only limited scope for formal training of the classroom variety, partly because of the nature of the subject and partly the type of trainee, many of whom would already consider themselves professionals since they will have obtained their certificates of competency in seamanship, navigation and so on. It was concluded that there was much more likelihood of success if advanced training aids and training simulators could be developed for the fishing industry. To a considerable extent this conclusion was affected by discussions with the Armed Services who have adopted such techniques to an ever-increasing degree over the last 20 years, and with considerable success. The basic objectives in the design and use of training aids are similar, namely the introduction of realism, the stimulation of interest and, in the most advanced systems, the ability for the trainee to actively participate.

It was also felt that courses of instruction would only be successful if each group of trainees was small, for example six or eight at most, and permit discussion between trainee officers, instructors and fisheries scientists and technologists.

SIMPLE TRAINING AID

On these considerations development started in 1969 on a relatively simple training aid as the first phase in what is expected to be an extensive development programme. Physically this initial training aid consists of a mock-up of the wheelhouse of a large British sterntrawler. The mock-up is equipped with most of the instruments available on fishing vessels of that type, and these instrument displays are capable of reproducing most visual and aural information available normally. The displays are fed from a tape recorder, with recordings taken at sea on a commercial fishing vessel. The recorder is a high-speed multi-channel instrument and the total electronic system is capable of recording simultaneously up to 16 quantities.

The aural information includes:

1. Radioed information from other ships fishing nearby or on other grounds
2. Radioed weather information
3. Instructions and other information from the home port

The principal visual information consists of:

1. Echo sounder cathode ray tube display
2. Chart records from echo sounders
3. Warp load meter displays
4. Ship's speed
5. Ship's heading

In parallel with the tape recordings it is possible to have cinematograph display of sea state and working deck.

Finally, and most important, a commentary by the captain of the vessel and by a fisheries technologist sailing with him can be recorded and replayed to the trainee.

The basic objective is to record at sea on commercial fishing voyages a very wide range of situations which arise day by day and hour by hour, requiring decisions by the captain, and to be able to replay them ashore to trainees along with a detailed commentary by the captain of the vessel concerned.

It is essential to have cooperation of a top captain. He must be able and willing to describe his interpretation of each set of information and to explain the reasons behind each decision. It is also essential that the captain has a high professional reputation.

The vessel used would have to be specially equipped and manned by a team of technicians and fisheries technologists. One important function of the latter is to encourage the captain to make a continuous commentary on situations as they arise or, at the very worst, to record sufficient notes of his own for the commentary to be inserted later on the tape. It is very difficult for the captain, particularly an experienced and successful one, to remember to discuss, aloud, his thoughts on points which to him are second nature but may be quite alien to trainees. The most important function of the trials team is to ensure that this is done.

This work imposes a heavy strain on the captain, over and above that of normal fishing and is only possible for short periods. For this reason the gathering of a suitable library of tapes is going to be a long and tedious process and at the time of writing only a small number have been obtained.

The wheelhouse and all associated electronic equipment have been built and it is hoped that the system can be used, experimentally at least, by late autumn 1970.

Advantages and limitations

The main advantage of this training aid is that it is capable of reproducing in a reasonably realistic fashion the various situations presented to the captain and the data available to him in reaching decisions. It thus affords the trainee the opportunity of discussing each situation with the instructors and preferably with the captain who took part in the original recordings. This discussion aspect is most important.

It should be possible, using this system, for trainees to learn the methods used by successful captains in interpreting their instrument displays, particularly those from the echo sounder which are notoriously variable and ambiguous.

The most serious limitation of this system, is that it is an entirely passive demonstration tool. The trainee cannot actively participate in the fishing operation being demonstrated, he cannot change the course of events, make his own decisions, mistakes, etc. However, as a "first generation" tool it is felt that it could make a significant impact upon training provided it is associated with courses of instruction on other topics.

TRAINING SIMULATOR

The White Fish Authority intends to exploit the "first generation" training aid as soon as possible. Nevertheless, the possibility of a fully-active training simulator is already under consideration, and it is hoped to attempt development of such a system over the next two or three years. Preliminary discussion with others who have built and operated such systems have indicated that the only feasible method will be to use a digital computer. The Norwegian Fisheries College has already started work along similar lines.

A real time simulator is envisaged which will allow a limited number of trainees, say four or five, to fish on a simulated fishing ground or group of grounds. All navigational and fishing aids normally found on modern vessels would be available and trainees would manoeuvre their vessels and their fishing gear as they would when exploiting a real situation. Each trainee would have a cubicle with his own instruments.

The digital computer would store and up-date all relevant information on:

1. Topography of fishing ground
2. Location of fish and other echoes in horizontal and vertical planes
3. Navigational information
4. Weather and sea state data
5. Tidal effects
6. Rough ground and sea bed obstacles

Each student would control his ship in speed and direction and would respond to signal output by the computer to act realistically.

Thus the computer would be required to store and use a variety of information relating such things as ship's speed to power, ship's direction to helm angle, the effect of wind and current on ship's speed and drift, etc. The system would have to be sufficiently flexible to allow the instructor to change weather and sea state and the distribution of fish.

The radar display would show other vessels in the vicinity duly distributed. Trainees would be able to identify each other on the radar and would provide their own VHF information by reporting over an intercom system what they were seeing on their instruments and what they had caught.

Of course, trainees would first be given basic information in charts, instructions from owners, synoptic weather reports, fishing information from other ships and so on.

The system should be capable of replaying complete exercises in order that instructors may hold post mortem discussions.

Advantages and limitations

In a simulator of this type trainees would be introduced to real fishing situations without actually going to sea. Their ability to set up and interpret their instruments would be thoroughly exercised and they would be put in a position where their ability to work up a particular fishing ground and to make the right decisions throughout a period of continuous intense fishing would depend almost entirely on their ability to interpret and assimilate information from their instruments, VHF, and so on.

Navigation, particularly as regards fishing, would be exercised and the trainees would have to learn to make allowances for weather and tide when attempting to steer their ship and trawl over the required course.

By changing the disposition of fish and species of fish it might be possible for the trainee to use different trawls in different situations and to see alternatives which can arise even in the course of a single day.

Main limitations of this simulator are likely to be financial because of the number of situations and variables which can be introduced. One other limitation is that available knowledge of the effect of changes of trawl and trawl rigging on catch rate is still extremely superficial.

One main attraction of the training simulator is that several trainee officers will be able to use it simultaneously and, if properly designed, they should be able to compete with one another in exactly the same way as they do in practice.

FISHING GAMES

Training simulators of the type described will only be within reach of countries prepared to spend large sums of money on national training facilities. In the absence of such facilities much cheaper systems may be considered, which may contain enough of the basic concept, and particularly the competitive aspect, to make them worthy of consideration. Such systems could be called "Fishing Games".

The most promising of these is that devised and partly constructed by Mr. W. Dickson of FAO, several years before the training aid described earlier was created.

Basically, the game consists of a series of cards representing the essential features of a fishing ground. This fishing ground has a series of separate areas or banks. Fish concentrations are shown on the cards in the form of echo sounder charts at each of several discrete depths, and at each depth the fish distribution in the horizontal and vertical plane can be seen. The echo sounder records also show differences in ground hardness. The game also contains a series of cards, charts and other basic information for "setting the scene" for each fishing voyage. For example, weather synopses are given in the form of transparent overlays to be put over the charts.

In the game each trainee selects a set of basic data giving weather synopses and state of fishing on each area of the fishing ground. He chooses which area to go to, and selects the appropriate cards. These will include a calibration tow across the ground, from the result of which he has to decide on the depth at which to fish and which fishing gear he will choose, based upon the fish distributions, bottom condition and so on. He then selects his next card, appropriate to his first full tow and this results in a catch and another echo sounder chart. The catch will depend on the gear he has chosen, as well as the fish distribution. From these results he then has to decide whether to continue in that area or to move.

Dickson's original concept was built around British wet-fish operations. Normally the game would be played by three or four trainees at once, each selecting his cards sequentially. The game can incorporate a reasonable number of decision-making aspects of the normal commercial fishing operation and compress them into a very short time scale.

One main drawback of the game is that it requires a very large number of cards, some containing echo sounder records, with considerable information, pictorial as well as written. Dickson's original game contains only three basic options namely:

Choice of one out of three fishing areas
Choice of one out of three types of gear
Choice of one out of four depths on each fishing area.

Even with that small number of options the number of cards to produce a time-varying situation and to include weather and market fluctuations totalled approximately 6,000. The cards are permanent in character so that any significant changes to the game would result in considerable reconstruction.

In spite of these limitations, it was the author's view, after playing the game that the concept had considerable scope and merited serious consideration by those engaged in the development of training systems for fishermen.

TRAINING IN OTHER SUBJECTS

In addition to methods for improving training in decision-making, there are other aspects of the captain's duties which impinge upon the decisions he makes. It is the intention of the White Fish Authority to try to build a training programme around modern training aids, including these associated subjects. These would include:

1. Choice of trawl and rigging of trawl for various distributions of fish and for different species
2. Handling, processing and stowage of the catch
3. Analysis and interpretation of meteorological data
4. Crew relations, morale and ship hygiene
5. Fisheries biology and marine science in general

In each case the subject would be dealt with on a broad basis, eliminating unnecessary scientific detail. Wherever possible the training would take the form of a discussion between trainee officers, instructors and technologists, and would be associated with realistic presentation using models, films and demonstrations (for example in fish processing plants).

The overall objective of the entire training programme would be to produce the skilled technologists required as captains of modern fishing vessels.

Acknowledgement

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DISCUSSION

SONAR

Tucker (UK) Rapporteur: Of the four papers not already partially discussed, we have only that by **Vestnes** which is concerned with what I may call "ordinary" sonar, that is, sonar as currently used in fishing. **Yuen's** paper deals with a very special kind of sonar—the CTFM (continuous-transmission frequency-modulated) sonar. **Margetts'** paper and my

own have this in common, namely that both are concerned (inter alia) with what is strictly called within-pulse electronic sector-scanning sonar, or "scanning sonar" for short.

Scanning sonar has been known for a long time, but has not aroused a lot of interest in fish-catching circles because it has been too expensive. For fisheries research there has again been a big delay while money was provided and a ship (the *R. V. Clione*) specially fitted with suitable transducer-stabilizing arrangements which also provide for vertical as well as horizontal scanning. But now **Margetts** can show practical results of observations made at sea with a 500 kHz high-resolution scanning sonar.

In my own paper I explain how I think that scanning sonar may prove valuable in fish searching and catching operations, because by the use of modern micro-electronics it may be made at a very low price; our "digital" sonar, so-called because it uses digital integrated circuits already available cheaply—offers a full sector-scan performance at a price of only one or two thousand pounds—well under $5,000, including transducers. It will also be possible to cheapen the kind of system which **Margetts** used, but I do not think the price can come down low enough to be competitive with ordinary sonars. I have hopes of the success of scanning sonar in the operational field because **Vestnes** says there is a need for increasing the speed of search by increasing the field of search covered by the sonar—which is just what scanning sonar does.

The question of whether the transducers of a scanning sonar need to be stabilized is a difficult one. For research on fish and gear behaviour, as discussed by **Margetts**, it is undoubtedly essential. I hope that for use in fish-catching, stabilization will prove to be unnecessary; if it should prove essential here too, then electronic stabilization as described by **Miyajima** and by **Pearce** and **Philpott** may be able to reduce the cost.

Micro-electronics is a theme which is stressed in the paper by **Mross** and **Purnhagen** as well as in my own. I think there was some misunderstanding in the discussion yesterday, for several speakers stated that what was wanted was not more complex sonar, but instead simpler equipment. I am sure this was wrong. What is wanted is surely more useful displays and greater reliability, indeed greater simplicity for the operator. This may now be achieved by using more complex electronics at quite low cost.

An important theme mentioned by both **Vestnes** and **Kudryavtsev** is that of variable-depth sonar—the former mentions serious operating difficulties in fishing work, but the latter gives a favourable report.

I will mention a few topics from various papers in the hope that they may form subjects of discussion:

In my own paper I discuss the matter of very-high-resolution possibilities for detailed observational work in the water, and also the use of non-linear acoustics.

Vestnes stresses the importance of dual sonar search (using sonar on the main boat and on a small boat) in purse-seining; also netsonde; and he thinks a Doppler sonar would be valuable.

Yuen's CTFM sonar, costing over $200,000, is too expensive for fishing operations, and I doubt if micro-electronics can reduce its costs to make it competitive with other systems. He says that information on the target is received throughout the sawtooth period, but I believe this is true only when the sonar is not scanning.

Suomala (USA): Asked for a definition of a fully stabilized transducer.

Tucker (UK) Rapporteur: A fully stabilized trasnducer is stabilized in roll, pitch and yaw.

Mitson (UK): There is an increasing realization of the need for transducer stabilization. With electronic sector scanning in the horizontal plane stabilization is essential. For forward searching using the scanning beam vertically, there is less need for stabilization. The seabed echo appears as a line which moves across the display as the ship pitches. Operators are able to observe targets relative to the seabed echo which acts as a reference.

Range is an important point: it must not be too short or the ship will be unable to manoeuvre relative to the target. If it is made very long there will be rather little detail shown. A reasonable compromise seems to be about 250 m for the types of target shown on the film by **Margetts.**

Resolution is discussed and calculated relative to particular targets. The equipment on board *R. V. Clione* can provide variable resolution within the 30° scanning sector from 0.3° to 1.66°. No amount of theorizing can have such an impact on the operator as does the visual lesson when such adjustments are made.

It is expected that electronic sector scanning sonar will be valuable in the observations of purse seine operations. As a result of the rapid developments in electronic micro-circuits, costs of such equipment should decrease. The CTFM equipment gives impressive results. If performance and costs could be optimized it might find commercial applications.

Vestnes (Norway): Why do some countries have success with sonar and others not? I have listed the necessary factors which govern success or failure in fishing with sonar:

1. Sea conditions—good or poor; 2. Fish—no fish, no success; 3. Sonar--good or bad, and its installation; 4. The ship—noisy or quiet; 5. The man—knowing his job or not.

I have tried to gather information from other countries in the world. Searchlight sonar is the most predominant in use today. Is one or more of these factors missing in some countries like South America or Africa?

Jakobsson (Iceland): The history of the evolution of sonar used in Iceland which started as a tool of research in 1953 is well known since it was discussed also at the last Conference. I am interested in towed transducers as we want to search with ranges of 3–4,000 m. That is our demand to the manufacturers. Sometimes this can be done with the usual sonar but often the thermocline limits the range. Towed transducers could possibly help us to get below the thermocline and thus increase the range.

Feu (Portugal): On my own vessels, I made the first experiments in Portugal with sonar. It has not been well accepted by fishermen in my country, partly because this equipment is not very easy to operate and partly because of the difficulties which fishermen often have in becoming acquainted with new gear without proper training.

Even more important is the fact that conditions in the Portuguese sardine fishery, that is, the distribution of the sardine schools, is different from those in the Icelandic or Norwegian herring fisheries. Sardine along the Portuguese coasts generally occur in irregular schools and are caught over water depths of 40 to 60 fm. Furthermore our sardine boats work in concentrated groups in small areas. Sonar records in these conditions cannot be well understood and fishermen therefore are not able to obtain good results.

Sonar also does not operate well in shallow water, because it is affected by bottom echoes, and I ask the sonar experts whether there are methods or equipment which help to overcome these problems.

Gudmundsson (FAO/Argentina): In Argentina there are very good sonar conditions and we have picked up anchovetta schools easily at a range of 1500 m even in 15–20 fm depths. Presently there is very little commercial anchovetta fishing but in future sonar will be indispensable as schools are rarely spotted visually.

Hellevang (FAO/Peru): Sonar conditions in Peru during the summer season are not as good as in the North Atlantic. 500 to 600 m appears to be the maximum range of any sonar equipment, which costs twice as much as in Norway. Since fish are frequently located from surface indications (birds or direct observation) the economics of buying a sonar at a very high price have to be considered carefully.

Ludwig (Germany): I am somewhat surprised at the general opinion of the limitations of sonar in shallow water. This has been solved successfully by bottom echo supression by electrical means. Such sonars are widely used in shallow water operation.

Ben Yami (Israel): Our shallow water problems start at about 10 m depths, while at 20 m we still have satisfactory recordings.

Gronningsaeter (Norway): It is important to link sonar observations with precise navigation.

Portier (France): In France sonar is used in midwater and bottom herring trawling with good results. Some influence of the noise of sonar on the behaviour of fish has been noticed.

Craig (UK): What is done to predict sonar conditions. Is this done by fishermen themselves or by research people?

Gudmundsson (FAO/Argentina): In Icelandic herring fishing we suffer sonar range limitations when thermocline conditions are bad in the fishing area, but no prediction of these conditions is made or given.

Okonski (FAO/Argentina): I can't imagine aimed midwater trawling without sonar. In Argentina we are fishing anchovetta between 18 to 200 m depth with good results. During the day we search for bigger concentrations, and during the night for more dense schools.

Proctor (Canada): The Canadian Department of Fisheries and Forestry has had developed a 6,000 ft range, high speed sonar with a PPI display which will undergo tests later.

A great deal of experience is available in Canada of towed sounders normally towed at about 20 knots; if anybody is interested we can supply them with information about this.

Traung (FAO): One problem in fish finding is the speed at which search can be conducted. We have discussed air spotting and it is described rightly as being a high speed search technique. Another possibility is the use of speed boats which can be made very sea-worthy but the problem is up to what speed will the acoustic gear function adequately for fish finding purposes. If it is necessary to reduce speed for actual search then the primary advantage of high speed is lost. Also we need to know whether or not towed bodies can be used at high speeds.

Proctor (Canada): High speed sounding has been used for several years in Canada with both hull-mounted and towed body units. Work has been predominantly hydrographic survey at speeds of, normally, 20 knots although trials have been made at 40 knots. The towing crafts have been launch, helicopter or hovercraft. From the successful results obtained, speeds up to 20 knots should not present any problems and the technique could be applied to fish finding.

Gerhardsen (Norway): This last remark makes it necessary to sound a warning against any too-optimistic views on the problem of searching for fish at very high speed. This is a problem which has not by any means been solved yet. Searching for submarines with a target strength of plus 30 decibels is something entirely different from searching for fish with a target strength of minus 30 decibels.

Olsen (FAO): The successful 1969 ICES/FAO acoustic course has already had a marked impact on the use of acoustic methods for fisheries research in various parts of the world.

Mross (Germany): Much effort is being made to teach skippers how to utilize acoustic equipment more effectively. Yet there is a gap. There is a strong demand for engineers to consider fish detection much more as a man-machine information system. It can be shown that a number of problems related to the information flow in the man-machine interface could be better solved by a more consequent application of human engineering principles. The kind, specifications and locations of various displays can be influenced accordingly, as well as the technique of operation, where logical linkage and automation of operational variables can reduce the number of controls. This will of course not eliminate the need for teaching. But we need to approach this problem from both sides, human engineering and teaching.

Frimannsson (Iceland): Several years ago the Icelandic Government wanted a sonar simulator, but we could not find one. When we finally got a price quotation from a manufacturer about two years ago the interest in sonar training had decreased so far that we did not invest in the simulator. Echo sounder and sonar training is mandatory in Icelandic Navigation Schools and continued training is now done aboard the boats. Crew members who are future captains, that is, those who have their captain's certificate, learn from captains. This takes many years and is not very satisfactory. We are therefore reconsidering and may acquire a simulator in the near future.

Alverson (USA): I have noticed that at every FAO conference of this type held in the past decade attention was given to the problems of training fishermen in the use of echo sounders and sonars. There is apparently much more dialogue than action. May I suggest that FAO considers the possibility of finding a mechanism for funding the development of simulators for this purpose and that the Secretariat investigate this possibility and recommend a source of action.

Craig (UK): I would like to remind that FAO has already set up a committee to do this very thing. Might it not be more appropriate if action is taken to reconvene this committee?

Subsequent to this Discussion, two committees were convened and the Report of Working Part B on Echo Sounder and Sonar Simulators is given here. Members were: R. Bennett (U.K.), R. E. Craig (U.K.), H. Frimannsson (Iceland), H. P. Knudsen (Norway), K. Olsen (Norway), J. B. Suomala (U.S.A.) and G. Vestnes (Norway).

The group noted that a working party (Working Party A) consisting of **Vestnes, Mitson** and **Forbes** had been convened at Svolvaer to consider a similar topic, but had not re-assembled.

The group would have welcomed more precise terms of reference from FAO; however it is agreed that there is need for simulators to aid in elementary and also in advanced training schemes. To satisfy the latter requirement would be costly, but some of the group felt this was the most important aspect.

The topic requires subdivision and the group sees this as follows:

Echo sounding I. Simulators for elementary training exist in Norway and the U.K. Neither of these is fully satisfactory and FAO is recommended to pursue this matter on the lines already recommended by Working Part A, to provide better elementary instruction for fishermen and biologists. The essentials are to provide

a variety of taped signals from different field situations and have means to replay these to various commercial sounders in such a way as to preserve the effects of adjustments of operational controls, bottom lock displays, etc.

Echo sounding II. There is a requirement for an advanced simulator that can be incorporated in a more general operation simulation system, e.g. simulation of total trawling situation. This requires to be an active system, i.e. such that the displayed record will change in accordance with changes of course or ground decided by the trainee. One possible way the group can see to arrange this is on the general lines outlined by **Suomala** at this conference, field data being of course necessary to ensure realism of the weather, bottom topography, ship and gear characteristics and fish distribution pattern to be memorized by the computer.

Sonar I. It was agreed that any sonar simulator must be active, i.e. it must respond to ordinary controls, to changes of tilt and bearing, and to ship manoeuvres imposed by the trainee. Nevertheless the group thinks it worthwhile to recognize two levels of complexity.

The simplest would give signals dependent on the sonar controls, school depth and size, and ship manoeuvres, and nothing else. It was reported that such systems were being designed in the U.K. and Norway but not yet built. FAO could be kept in touch with the details and cost. This system might be developed for worldwide fishermen's training, being directed particularly to purse seining.

Sonar II. Such a system as above leaves out many operational problems, such as refraction, presence of ships wake and various tactical features. It was reported that investigation had been made in the U.S. of advanced computer simulation which could be developed to provide advanced training. Refraction had already been introduced, and such factors as effects of waves on the ship with changes in course could perhaps be simulated. The group advises FAO to keep in touch with this developing programme.

Summary

FAO action is recommended now on Echo sounding I and Sonar I. It is further recommended that a working party with practical experience of commercial fisheries and electronics be set up to refine the possible action on **Echo sounding II** and **Sonar II.**

PART II

PURSE SEINING

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History of Purse Seining in Japan

M. Inoue

Historique de la pêche à la seine coulissante au Japon

Venant des Etats-Unis, la pêche à la seine coulissante fut introduite en 1882 au Japon, où elle remplaça graduellement les seines tournantes et les seines de plage traditionelles employées dans les pêcheries de sardines. Par la suite, l'industrie de la pêche à la seine fut mécanisée et les navires et les engins furent agrandis et devinrent aptes à des opérations plus éloignées. Il en résulta une augmentation des captures de sardine jusqu'en 1936, puis celles-ci commencèrent à décliner en raison de la surexploitation, de mauvaises conditions de survie provenant de facteurs océanographiques défavorables, et/ou de la migration des stocks en dehors des fonds traditionnels. Après la deuxième guerre mondiale débuta une deuxième période importante de développement des bateaux et de l'équipement, faisant suite à l'introduction des équipement de pêche et de télécommunication électroniques et acoustiques et des fibres synthétiques. Ceci autorisa de plus grands navires et engins, une capacité de détection plus efficace du poisson et le développement de nouveaux fonds; il en résulta l'épuisement de certains stocks de sardine, avec par conséquence l'orientation de nombreux navires vers d'autres pêcheries. La pêche à la seine coulissante du listao débuta en 1913, pour se développer en tant que pêche côtière jusqu'en 1935, où les stocks se déplacèrent vers le large, hors de portée des navires, en provoquant un déclin de cette pêche. Après la deuxième guerre mondiale, on introduisit avec succès les plans de la seine coulissante à thon américaine et vers 1953 une flottille d'environ 20 bateaux de la classe des 100–150 tx fut reconvertie à cette pêche. Depuis lors un changement s'est accompli en faveur de la pêche à la seine coulissante à deux bateaux.

Antecedentes de la pesca con redes de cerco de jareta en Japón

Las redes de cerco de jareta llegaron al Japón procedentes de los Estados Unidos en 1882 y gradualmente sustituyeron a las de cerco y de playa tradicionales empleadas en la pesca de la sardina. Posteriormente se mecanizó la pesca con redes de cerco de jareta, aumentaron las dimensiones de los barcos y de los artes y con ello se pudieron explotar caladeros distantes. Los resultados fueron que las capturas de sardina aumentaron rápidamente hasta 1936, año en que comenzaron a disminuir por efecto de una pesca excesiva, factores oceanográficos adversos debidos a una mala sobrevivencia o emigración de las poblaciones de los bancos de pesca tradicionales, o ambos. Después de la Segunda Guerra Mundial comenzó un segundo período muy importante de perfeccionamiento, como resultado de la adopción de la pesca y equipo de comunicaciones acústicos y electrónicos y de las fibras sintéticas. Gracias a ellas se pudieron construir barcos y equipos mayores, preparar métodos mejorados de localizar peces y explotar de nuevos caladeros, lo que a su vez dio de nuevo por resultado el agotmiento de algunas poblaciones de sardinas y el que muchos barcos se dedicarán a otra clase de pesca. La pesca de listado con redes de cerco de jareta comenzó en 1913 y como actividad costera se amplió hasta 1935, año en el que las poblaciones se alejaron de la costa y por tanto del radio de acción de los barcos con lo cual declinó esta pesquera. Después de la Segunda Guerra Mundial se adoptó satisfactoriamente la red de cerco de jareta norteamericana y para 1953 la empleaba una flota de unos 20 barcos de 100 a 150 toneladas que anteriormente había practicado otra pesca. Desde entonces se ha vuelto a pescar el atún con dichos artes, pero manipulados por dos embarcaciones.

PURSE seining started in Japan in 1882 with the introduction of purse seines from America. After that the round-haul-net, a general term for purse seine, lampara net and other surrounding nets, gradually changed until now (1969) purse seines account for over 80 per cent of all round-haul-nets. Before 1882, round-haul-nets, particularly the "Agri-ami" for catching sardines[1], had been used from the beginning of the nineteenth century and required 50 men to operate. Others were the "Makase-ami" which needed hundreds of men to operate and a small net called "Rokunin-ami" operated by six men. These nets were generally inefficient.

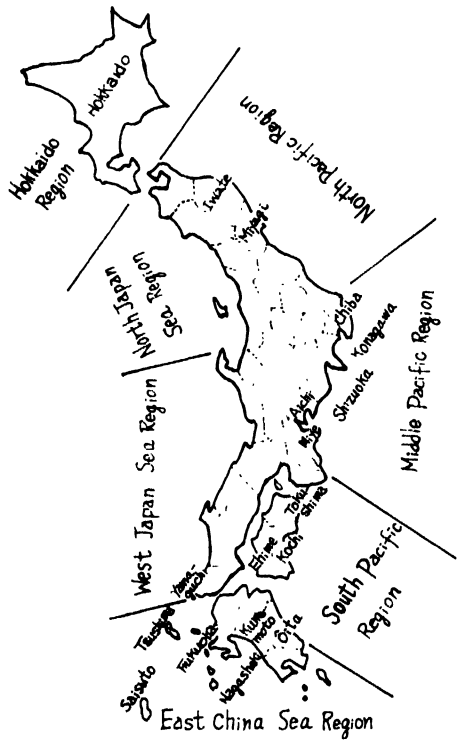


Fig 1. Prefectures and main sea fishing areas of Japan

Current Japanese purse seines may be divided into three types: sardine, mackerel/horse mackerel, and skipjack/tuna. As the horse mackerel/mackerel seine is very similar to the sardine purse seine it is described with the sardine purse seine. Figure 1 shows the various prefectures and fishing area.

Sardine purse seine

Introduction of the purse seine was accomplished in three ways: (1) by conversion of the traditional "Agri-ami", mainly in the Middle Pacific Region; (2) change from inefficient beach seines in the North Pacific Region; and (3) introduction into commercial fisheries by the Japanese Fisheries Agency (see fig 2).

In southern Japan some fishermen tried the American type purse seine under the guidance of the Fisheries Agency, but results were poor because the construction of the net and vessels was not suitable to local conditions and Japanese crews were inexperienced with this novel net. Therefore, during the period of 1894 to 1897 the fisheries experimental stations engaged in training fishermen in purse seines modified to suit fishing grounds and vessels of Japan. After successful operations, fishermen

[1] "Sardines" here refers to sardine (*Sardinops melanosticta*), anchovy (*Engraulis japonica*), and round-herring (*Etrumeus micropus*).

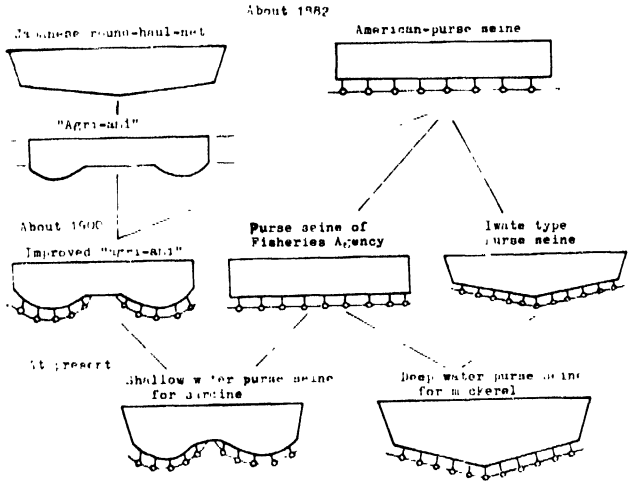


Fig 2. The development of purse seines and the general outlines of the nets

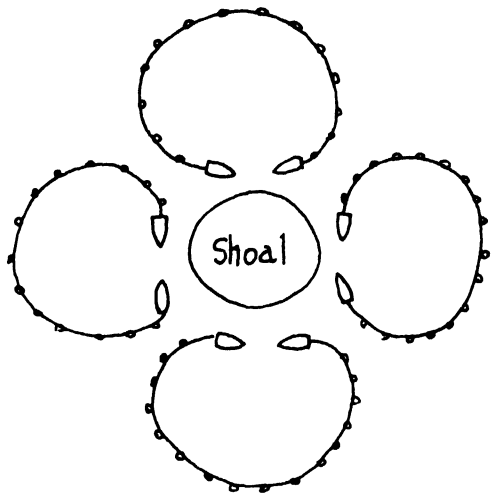


Fig 4. A fishing method using four seines to take a very large schoo

gradually began adopting it. The purse seine used in America in the period when it was exported to Japan was about 300 m in length and 32 m in depth. The typical purse seine constructed by the Fisheries Agency in Japan was 275 m in length and 38 m in depth (fig 3).

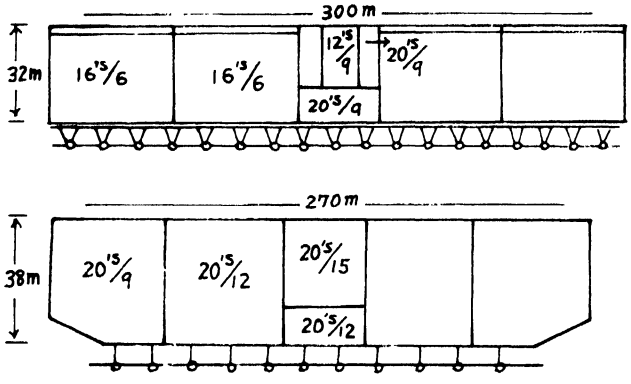


Fig 3. General specifications of a typical American purse seine in about 1890 (above) and the purse seine constructed by the Fisheries Agency in Japan 1893 (below)

One of the interesting operating techniques developed in about 1930 is that shown in fig 4. When a very large school was found which would have been difficult to catch with a single seine, four seines were set around the school and the fish was divided equally by the vessels. Such large schools have now become rare. Another method used in mackerel purse seining was a driving net (fig 5) to prevent fish from escaping the seine. This is not used any longer since mechanization permits rapid setting and pursing.

The catch of sardines increased rapidly from about 1910 and reached the maximum level in 1936. Since then it has gradually decreased. The cause of this is not known, but it may be due to overfishing, poor survival and/or migration outside the traditional fishing grounds.

The history of catches by gear during the decline of this fishery demonstrates the superiority of the purse seine. A comparison of the catch of sardine by three

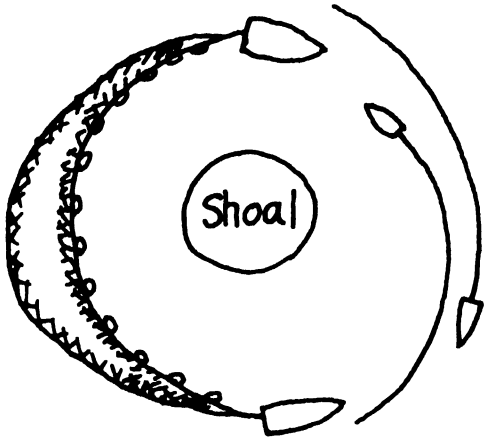


Fig 5. Mackerel purse seine with encircling nets

kinds of gear: purse seines, trap nets and gillnets in North Korea where a large sardine fishery existed at this time shows the total catch by the three methods reached a maximum in 1939 and then declined. The figures showed that in spite of the decrease of the stock of sardine from about 1935 the purse seine continued to take increased catches until 1939. This was probably due to the mobility of the gear as compared to the passive gillnets and trap nets.

After World War II the purse seine fishery advanced by the use of echo sounders, radio telephones, and synthetic fibres. This may be considered as the second revolution in the history of the purse seine fishery the first being the mechanization of boat and winch in about 1920. The use of fish echo sounders had a strong effect not only on the fishing power of the vessels but also on the development of new fishing grounds. Radio telephones were introduced into the purse seine fishery in 1947. Through close cooperation between fishermen, this instrument permitted reduced search time for all vessels. The first test of synthetic fibres was made with Amilan (nylon) in Nagasaki prefecture in 1950.

The general pattern of increase in vessels and gear size of the purse seine fleets in Nagasaki prefecture from

TABLE 1. BOATS AND NETS OF NAGASAKI PURSE SEINE FLEETS

Year	*tonnage (t)*	*Horse power (hp)*	*Dimension of net (m)*	*Fleet*	*Fish lamp (candle power)*	*Fish finder*	*Catch per fleet (t)*
1935	16.3	46.3	D60–90 L370–450	S1 LB2	8/1000	0	680
1940	17.1	48.3	D60–90 L450–750	S1 LB2	8/1000	0	unknown
1945	19.4	60.0	D60–90 L450–750	S1 LB2	1/2000	1 fleet	440
1950	32.1	100.5	D90–120 L900–1400	S1 LB2	2/3000	½ of whole	1090
1953	50.1	108.7	D160–190 L1300–1800	S2 LB2 T1	2/3000	whole fleet	1200
1955	53.6	181.5	D160–190	S2 LB2 T2	3000	whole fleet	1920

S = Seiner. LB = Light boat. T = Transport.
D = Depth L = Length

1935 to 1955 is shown in Table 1. This has occurred despite a steady decline of the sardine fishery of the East China Sea and of the anchovy stocks in the North and Middle Pacific Regions. As a result of these reduced catches, some anchovy purse seine fishermen entered the North Pacific skipjack and tuna purse seine fishery which has gradually increased since World War II. Part of the sardine fleet also switched to the horse mackerel and mackerel fishery in the East China Sea. This stock is especially abundant in the vicinity of Tsushima in Nagasaki prefecture and Saishuto, in Korea. Since the fish are a great distance from port and in deeper water, the vessels and gear have become larger.

Skipjack and tuna purse seining

Before introduction of the purse seine there were three round-haul nets used for skipjack and tuna: the skipjack "Aguriami" in Aichi prefecture, skipjack "O-ami" in Kochi prefecture and tuna "Maki-ami" in Miyagi prefecture. Since 1882 the skipjack "Aguri-ami" and tuna "Maki-ami" have been improved and developed as purse seines, but the skipjack "O-ami" had gone out of use.

Figure 6 shows the method of working the skipjack "Aguri-ami". The net was approximately 800 m long and 80 m deep and was mostly made of straw fibre except the bag net which was of hemp. The size of mesh ranged from 12 to 30 cm stretched. The net is operated with two boats, one is a seiner with a crew of 30 and the other is an auxiliary boat with a small crew.

The skipjack "O-ami" was divided into three parts: the encircling net, the bag net and the driving net (fig 7). The encircling net was approximately 500 m long and 60 m deep and the size of mesh was very large. The bag net was made of hemp and was 30 m in circumference and instead of floats was held on the surface by 10 to 11 small boats with one to two fishermen each. In operation, as soon as a school was surrounded with the encircling

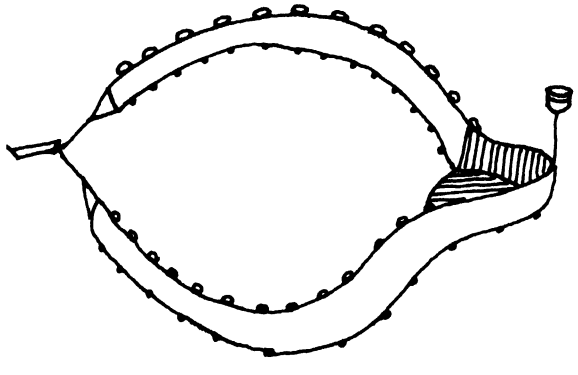


Fig 6. Scheme of skipjack "Aguri-ami" operation

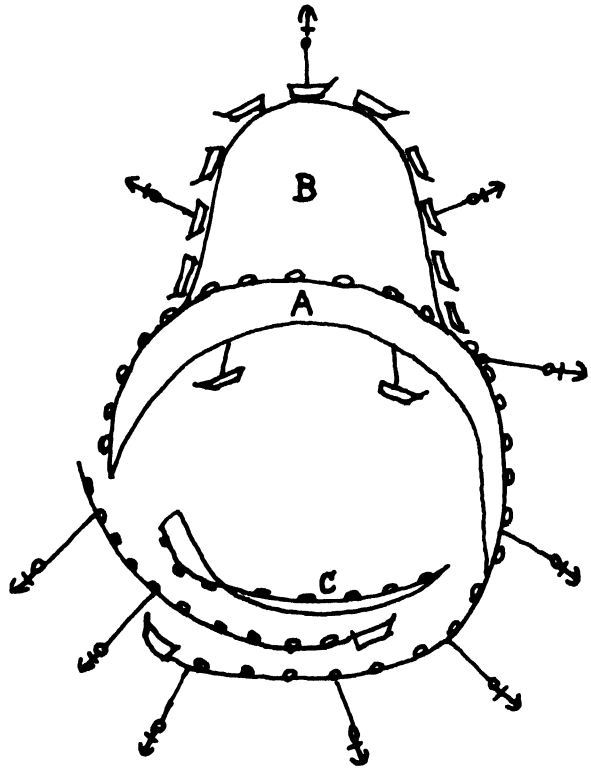


Fig 7. "O-ami"

net (A), which was held in place with several anchors, the driving net (C) was used to scare the fish down into the bag net (B). This system required about 15 boats and 100 crew.

Originally, the tuna "Maki-ami" was a kind of surrounding gillnet, but was modified to a round-haul net with a bag. However, as the fish coming into the bag net could easily escape, a panel of netting attached to the forward edge of the bag was lifted with ropes to block the escaping fish (fig 8). The bag net was 37 m long and 27 m deep and the wing net was 375 m long and 15 m deep. The net was operated by 25 fishermen on three boats.

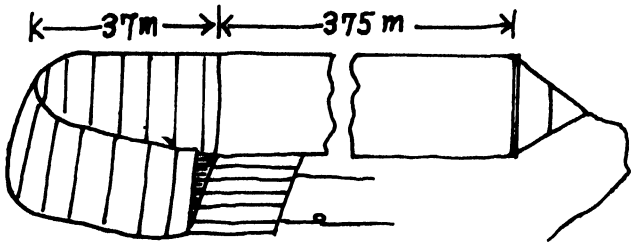


Fig 8. "Maki-ami"

In 1948, purse seining for tuna was advanced by introduction of the American purse seine. The Tokyo Fisheries Company carried out initial experiments and as a result of its success over 20 American-type purse seiners of the 100 to 150 ton class appeared between 1949 and 1953. Figure 9 shows the most standardized type of tuna and skipjack purse seine used then. In addition, since the sardine purse seine fishery had begun to decline in the North Pacific, many changed to skipjack and tuna purse seining with boats constructed for this fishery. After many modifications of the nets, boats and fishing methods, most of the purse seining for tuna and skipjack in Japan is now carried out by the two boat system. This has some advantages for catching tuna and skipjack, in that encircling is quicker and the net is larger than with the one boat purse seine.

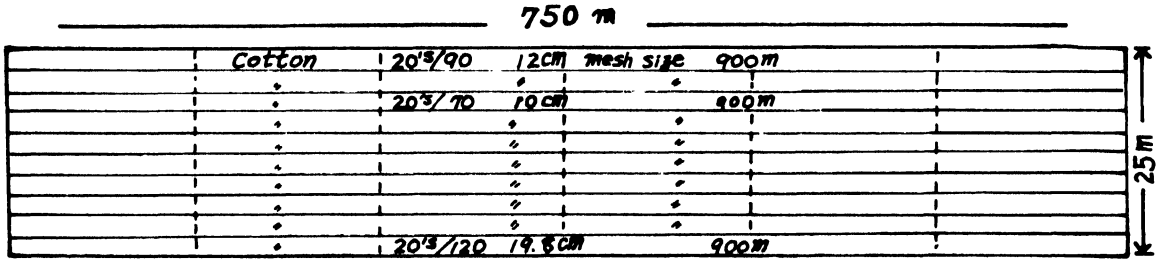


Fig 9. Typical Japanese tuna purse seine in 1950 is very similar to American purse seines

The Purse Seine Fishery in Japan

T. Akaoka

La pêche a la seine coulissante au Japon

L'industrialisation croissante du Japon a provoqué une ponction sur le personnel des industries de base, telles que les pêches, d'où une grave pénurie de main-d'oeuvre dans la pêche à la seine coulissante. On s'est efforcé de trouver des solutions à ce problème en améliorant les conditions de vie des pêcheurs à bord, en intensifiant la mécanisation des opérations pour réduire les besoins en main-d'oeuvre spécialisée et en insistant sur la qualité du poisson pour accroître les recettes.

La pesca con artes de cerco en el Japon

En el Japón la creciente industrialización ha ido absorbiendo numerosos trabajadores de las industrias básicas. En el caso de la pesca, eso ha motivado una grave escasez de mano de obra en la pesquería con artes de cerco. Se intenta resolver este problema mejorando las condiciones de vida de los pescadores a bordo, aumentando la mecanización de las operaciones de pesca, para reducir la necesidad de personal capacitado, y mejorando la calidad del pescado, para obtener mayores beneficios.

MANUFACTURING industries in Japan have absorbed workers from fisheries. As a result, the recruitment of young fishermen has decreased and the average age of fishermen is rising. To attract young and competent crew for the purse seine fishery, a tendency has developed to introduce electronic instruments and deck machinery to reduce the number of crew and improve the living conditions on board.

Classification of this fishery

According to Government statistics for 1967, the total number of purse seiners was about 1,500 with an annual production of 1,153,167 tons, which was 16 per cent of the total catch in Japan (Table 1).

The purse seine fishery is classified into three groups:

(1) Small type purse seine fishery operated all round Japan

TABLE 1. COMPOSITION AND CATCH OF THE JAPANESE PURSE SEINE FISHERY IN 1969

	Type of operation	Number	catch	
			ton	%
Small type	One-boat type	663	119,246	10.3
	Two-boat type	480	238,474	20.6
Northern Japan	One-boat type	17	54,671	4.8
	Two-boat type	156	292,476	25.4
Southern Japan	One-boat type	178	441,280	38.3
	Two-boat type	3	7,020	0.6
Total	One-boat type	858	615,197	53.4
	Two-boat type	639	537,970	46.6
Grand total		1,497	1,153,167	100.0

TABLE 2. THE CATCH IN TONS OF THE JAPANESE MEDIUM AND LARGE PURSE SEINE FISHERY ACCORDING TO SPECIES

Fishing ground	*Type of operation*	*Sardine*	*Spanish mackerel*	*Horse-mackerel*	*Tuna and skipjack*	*Others*	*Total*
Northern Japan	One-boat type	11,395	9,270	107,211	4,241	581	132,698
	Two-boat type	75,038	1,573	202,714	13,434	6,140	298,899
	Total	86,433	10,843	309,925	17,675	6,721	431,597
Southern Japan	One-boat type	8,509	244,608	93,831	1,042	15,263	363,253
	Two-boat type	—	—	597	—	—	597
	Total	8,509	244,608	94,428	1,042	15,263	363,850
Grand total	One-boat type	19,904	253,878	201,042	5,283	15,844	495,951
	Two-boat type	75,038	1,573	203,311	13,434	6,140	299,496
	Total	94,942	255,451	404,353	18,717	21,984	795,447

(2) Medium and large type purse seine fishery for tuna, skipjack, horsemackerel and sardine operated in the North Pacific Ocean

(3) Medium and large type purse seine fishery for horsemackerel, Spanish mackerel and sardine operated in the southern waters of Japan including the East China Sea and the Japan Sea (east coast of Kyushu).

In general the two-boat purse seine is more common in northern Japan and the one-boat purse seine in the south.

The species composition of the Japanese purse seine fishery catch is shown in Table 2, which does not include the catch of small type purse seines.

Reorganization of the fishery

Recently, several main developments have been noticeable in the purse seine fishery. Recruitment of crew can be solved by improving living conditions on board the boats and assuring financial stability. At the same time, efficiency must be improved to increase production and cover expenses of improvements.

Up to 1960, the fishing industry ranked among the leading industries in Japan. Now it is quite difficult to keep up with shore industries.

Economic reorganization of the Japanese purse seine fishery is being promoted by active and passive approaches. The active approach aims at securing better safety of operation and improving living conditions by increasing the size of vessels. For fish finding, there are used sonar and echo sounders. Furthermore, semi-automatic deck machinery, driven by electric or hydraulic power, is installed to reduce human labour. The passive approach attempts to modify the design of the boats and gear to reduce cost of operation and improve handling of the catch to obtain higher prices. Both approaches are promoted simultaneously and complement each other.

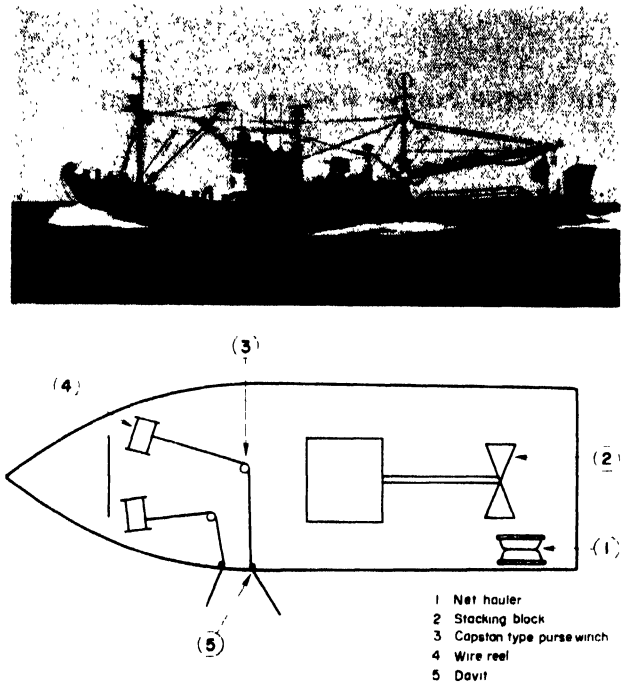


Fig 1. Typical one-boat tuna purse seiner (Eiun-Maru No. 1) *from southern Japan (net hauling over the stern)*

Technical developments

Hulls are being modified to improve the stability and enlarge living quarters. Air conditioning is also being installed.

According to statistics, the use of medium or high-speed engines is gradually increasing. This saves space which can be used for installation of heavy deck machinery and enlarging the fish hold; with more power, the boats can use larger and more effective fishing gear.

It is impossible to decide which is better, one-boat or two-boat operation, because each has its own merits and demerits; however, there is a general tendency to change from two-boats to one. The improvement in safety and living conditions, the installation of advanced deck machinery and the decrease in crew increases the economic efficiency of the one-boat method so much that it compensates for lower fishing performance.

The method of stern purse seining is a good example of the new trend. Economic efficiency is achieved by two means:

(1) The use of semi-automatic fishing machines like the purse winch, power block, net shifter and net hauler to decrease the number of skilled crew.

(2) Handling and storing the catch more carefully with crushed ice or refrigerated sea water so as to maintain high quality fish and thus obtain better prices.

Typical Japanese one-boat purse seiners with a schematic drawing of their deck layout are shown in fig 1 and 2 and their specifications in Table 2. The schematic construction drawing of a typical one-boat mackerel purse seine is given in fig 3 and of a typical tuna and skipjack purse seine in fig 4.

It is expected that the improvements outlined above will place Japanese purse seining at a high scientific and economic level.

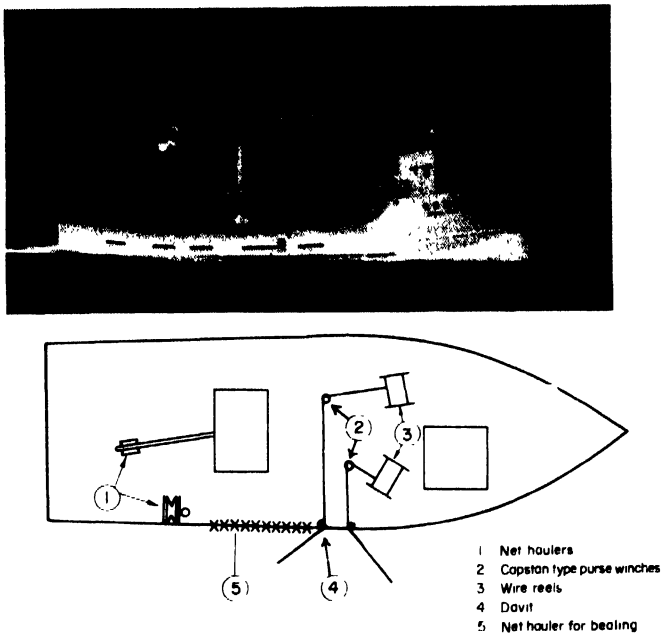
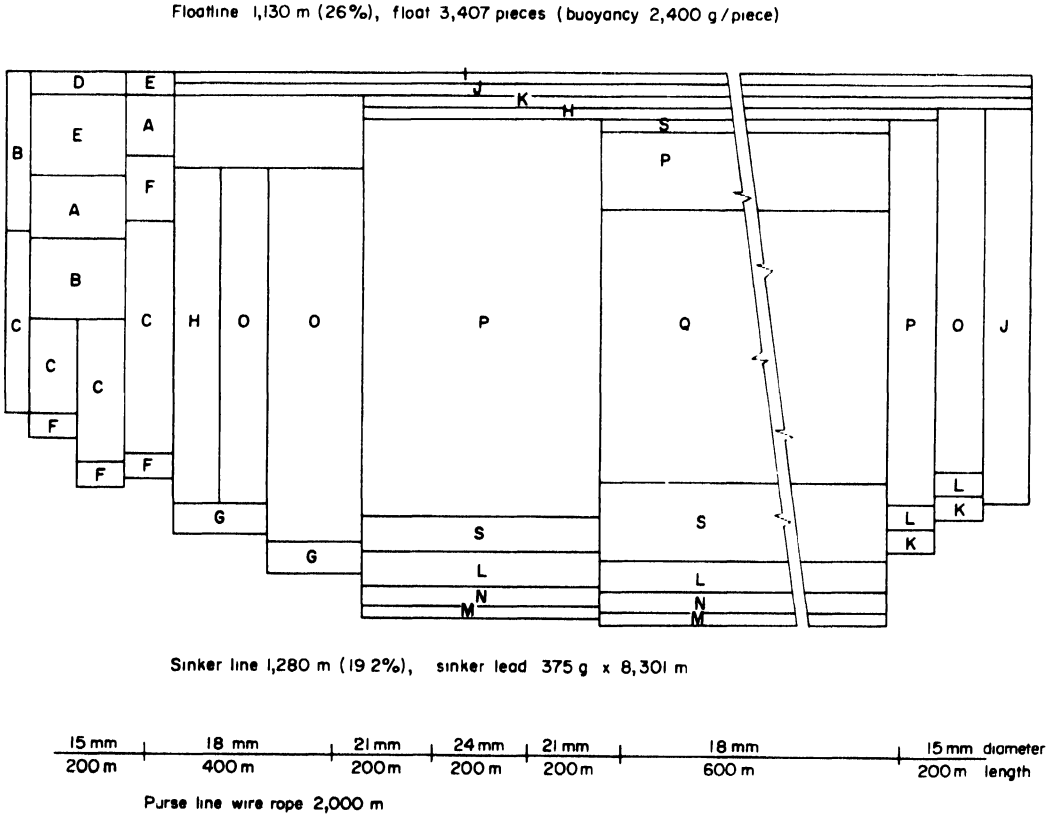


Fig 2. Typical one-boat tuna purse seiner (Zensei-Maru No. 15) *from northern Japan (net hauling over the side)*



SECTION	Material and mesh size (stretched) mm	Length (100 m deep x length) m
A	N 36,34	780
B	" 30,38	910
C	" 24,38	2,120
D	" 60,43	182
E	" 45,43	697
F	" 30,43	515
G	" 24,43	910
H	" 21,43	2,030
I	" 30,50	1,425
J	" 27,50	1,425
K	" 24,50	2,700
L	" 21,50	5,940
M	" 36,60	1,210
N	" 21,60	2,420
O	VF 18,43	5,000
P	" 15,43	18,850
Q	" 12,43	31,800
R	" 18,50	1,240
S	" 15,50	12,400

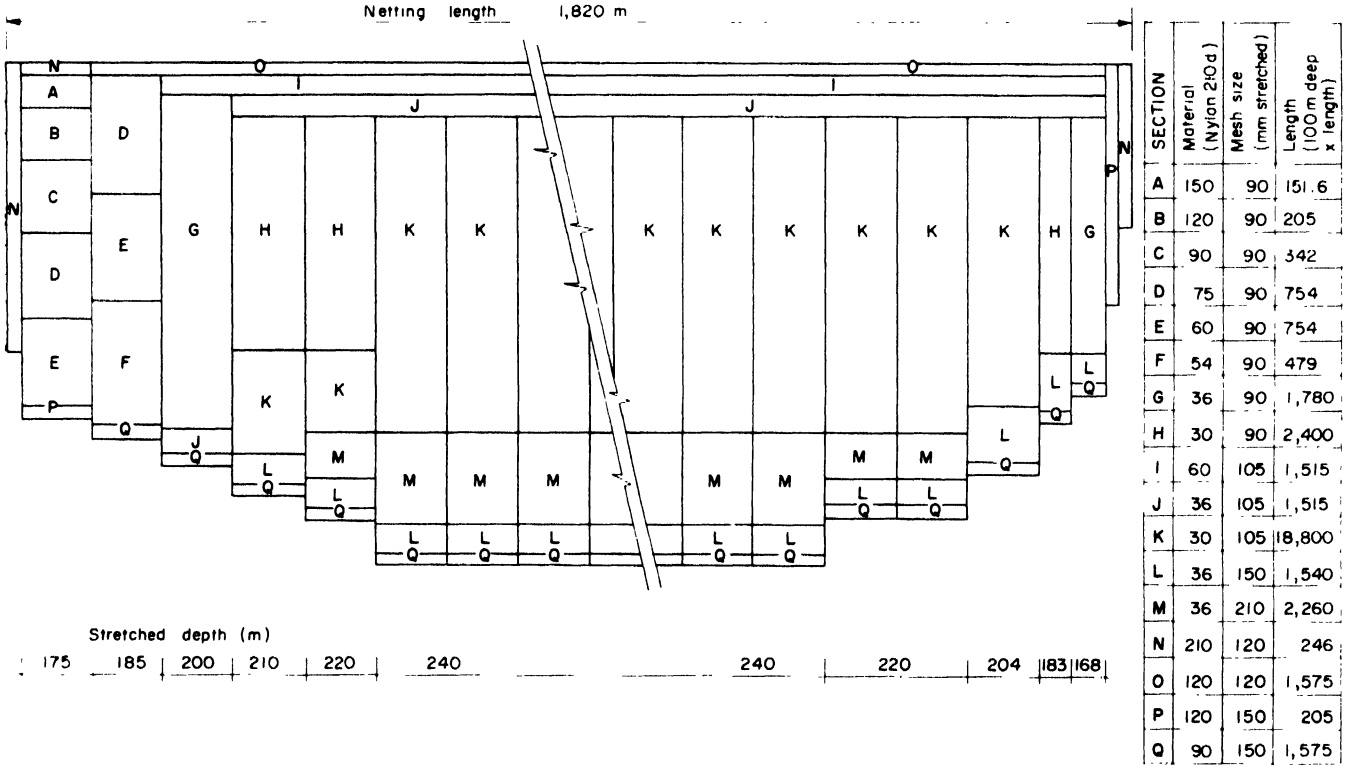
N = Nylon 210d
VF = Vinylon filament 250d

Fig 3. Mackerel purse seine, 111-ton one-boat type, northern and southern Japan

TABLE 3. SPECIFICATIONS OF TWO TYPICAL JAPANESE ONE-BOAT PURSE SEINERS

	Southern Japan EIUN-MARU No. 1 (stern hauling)	*Northern Japan ZENSEI-MARU No. 15 (side hauling)*
Gross tonnage	111.57	111.49
Hull	Steel	Steel
C × B × D	29.85 × 6.70 × 280m	29.65 × 6.78 × 280m
Main engine	1,150 hp	900 hp
Maximum speed	12.0 kn	12.9 kn
Cruising speed	11.7 kn	12.6 kn
Complement	25	22
Fish hold	39.77 m^3	61.12 m^3
Auxiliary fishing equipment	Japanese net hauler	Power block
	*Net shifter	Echo sounder, sonar (double frquency type)
	Echo sounder (two)	(28KC and 200KC)
	Purse winch (capstan type)	Purse winch (capstan type)

*Net shifter: Machine to divide the floatline from leadline of the purse seine net when hauling.



SECTION	Material (Nylon 210d)	Mesh size (mm stretched)	Length (100 m deep x length)
A	150	90	151.6
B	120	90	205
C	90	90	342
D	75	90	754
E	60	90	754
F	54	90	479
G	36	90	1,780
H	30	90	2,400
I	60	105	1,515
J	36	105	1,515
K	30	105	18,800
L	36	150	1,540
M	36	210	2,260
N	210	120	246
O	120	120	1,575
P	120	150	205
Q	90	150	1,575

Fig 4. Tuna and skipjack purse seine, 110-ton one-boat type, northern Japan

Light Attraction in Japanese Fisheries

C. Miyazaki

L'attraction par la lumière dans les pêches Japonaises

L'attraction du poisson par la lumière est utilisée au Japon pour les pêches à la seine coulissante (sardine, maquereau, chinchard), au carrelet y compris le bouke-ami (sardine, chinchard, orphie) et à la ligne (seiche, maquereau, chinchard). Les lampes non immergées et immergées sont employées soit à bord de bateaux porte-feux (pêche à la seine coulissante) soit sur le bateau de pêche lui-même (pêche au carrelet et à la ligne). L'équipement pour la lumière est entièrement électrique et l'on se sert à la fois de lampes à incandescence et à fluorescence. La puissance maximale des générateurs destinés aux bateaux porte-feux ou aux unités de pêche est réglementée par la législation. Une description succinte des trois principales techniques de pêche est fournie.

La pesca con luces en el Japon

Los japoneses emplean la luz para atraer peces cuando pescan con redes de cerco (sardina, caballa, jurel), con salabardos, comprendido el "bouke-ami" (sardina, jurel, papardo) y con caña (calamar, caballa, jurel). Las lámparas, que se colocan encima o debajo de la superficie del agua, se montan en botes auxiliares (pesca con redes de cerco) o en el propio pesquero (salabardos, pesca con caña). El equipo de iluminación es todo eléctrico y se emplean lámparas incandescentes y fluorescentes. Está reglamentado por ley el rendimiento máximo de los generadores para les embarcaciones que llevan las lámparas o para las unidades de pesca. Se describen brevemente las tres técnicas de pesca principales.

IN Japan fish lamps are used for:

sardine, horse mackerel and mackerel purse seine fishery

sardine, horse mackerel and saury pike stickheld dipnet fishery, and for

cuttlefish, horse mackerel and mackerel angling.

There are two types of fish lamps—underwater lamps and those used above the surface. Nowadays, both incandescent lamps, and fluorescent lamps are in use, but Japanese fisheries law regulates the total capacity of generators per boat, and the number of bulbs and light intensity. In some areas light fishing is prohibited.

LIGHTS USED IN PURSE SEINING

One-boat and two-boat purse seines are used in the horse mackerel and mackerel fishery and these operate with fish lamps in fishing grounds south of Central Japan.

In **One-boat purse seining** a net operation unit consists of the following vessels:

One purse seiner, 90–110 t, 500–550 hp or 700–850 hp

Two lightboats (fig 1), 30–35 t, 40–200 hp.

One fish detection boat, 30–35 t, frequency of fish finders 14 to 200 kHz

One carrier, 100–200 t.

The capacity of generators per boat is legally limited to not more than 10 kW. Each boat uses four to five ordinary lamps (each 1 kW) and two underwater lamps (each 2 kW) (fig 1). The latter are lowered to a maximum depth of 100 m.

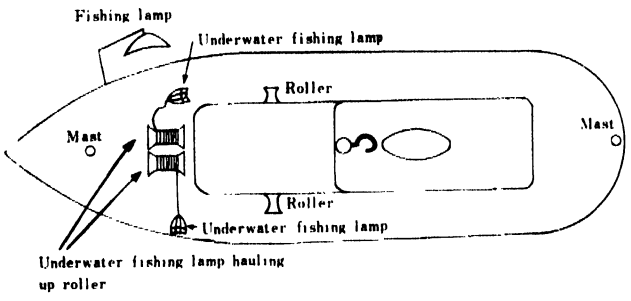


Fig 1. Layout of light-boat for horse mackerel and mackerel purse seining

The fish detection boat is also equipped with a generator (less than 7.5 kW according to the law) and is engaged not only in finding fish schools but also in gathering fish with surface lamps (1 kW) and underwater lamps (2 kW).

The purse seiner fishes in waters up to a depth of 200 m with a net, the floatline of which is 1,040 m in length.

The two lightboats alternately gather schools of fish without attenuating their light intensity.

The most common fishing method is to detect fish schools at night by echo sounder, attract the fish with lamps, and then catch them.

Two-boat purse seining takes place off the Japanese Pacific Coast, and fishing units consist of the following vessels:

Two purse seiners	39 t	150 hp
Three lightboats	6 t	45 hp

Under the prefectural fishery law, each lightboat has a generator (DC 105 V, 5 kW) and uses one ordinary fish lamp (2 kW) and one underwater lamp (1 kW) on each side.

When the lightboats have gathered fish, the two purse seiners set the net against the current surrounding the fish. At the time when both ends of the net are hauled on board, the lightboats go out of the net over the floatline which is 1,000 m in length.

Usually, just before setting the net, the lights are dimmed gradually to make the fish crowd more densely.

With small purse seines having a floatline length of only 160 m the light intensity of 1000 W is lowered first to 100 W and finally to 80 W.

LIGHT ATTRACTION WITH BOUKE-AMI NET FOR SAURY

The bouke-ami boats (fig 2) range from 10 t to 160 t in capacity.

As a number of boats operate on one fishing ground, the total capacity of generators per boat is limited to 30 kW and the number of bulbs for fish lamps is restricted to 50.

There are two kinds of fish lamps; one to lure fish to the boat's side after being detected by a search light (3–5 kW) or by echo sounder, and the other to guide the attracted fish to the other side of the boat (where the net

is ready for hauling-out) to concentrate them more densely.

One of the examples is that three sets of daylight fluorescent attraction lamps (a set consists of 30 W × 4 lamps) and two sets of daylight incandescent lamps (a set 500 W × 2 lamps) are fixed on each side of the vessel at the bows.

Four sets of red-incandescent fish gathering lamps, a set of daylight incandescent lamps, two sets of daylight fluorescent lamps (a set 30 W × 4 lamps) and 6 sets of daylight incandescent lamps are employed on the central port side (net-cast side) (fig 2).

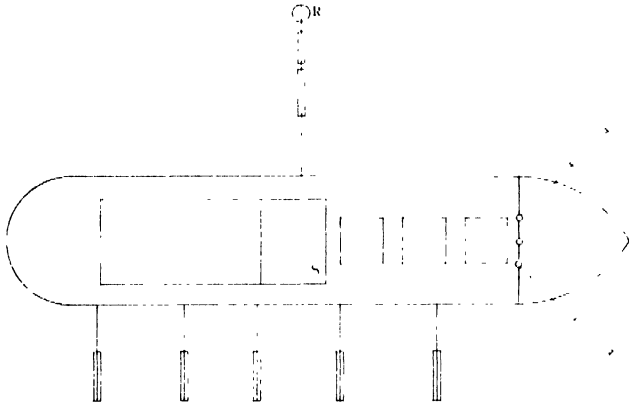


Fig 2. Fish lamp arrangement for saury pike stickheld dip net boat. S = searchlight, R = red lamp

The number and type of fish lamps differ with tonnage of the boats.

Upon detecting saury pike the bouke-ami boat slows down and all the fish luring lamps are switched on. Before the fish attracted by the lamps begin to gather around the boat, the net is lowered into the water. As soon as all the starboard lamps are switched off, the lamps on the portside must be switched on to guide the fish into the net. These are then gradually turned off keeping only the red lamps working until the net is hauled.

Incandescent surface lamps (30 kW) lure saury pike in layers from 0–40 m deep and three sets of blue-white fluorescent lamps (a set consists of ten 20 W lamps) and three sets of green (a set consists of ten 20 W lamps) are effective from 3 to 60 m in depth. (Suzuki and Asari, 1964, unpublished.) The boat is equipped with a net-hauler, linehaulers and a side roller.

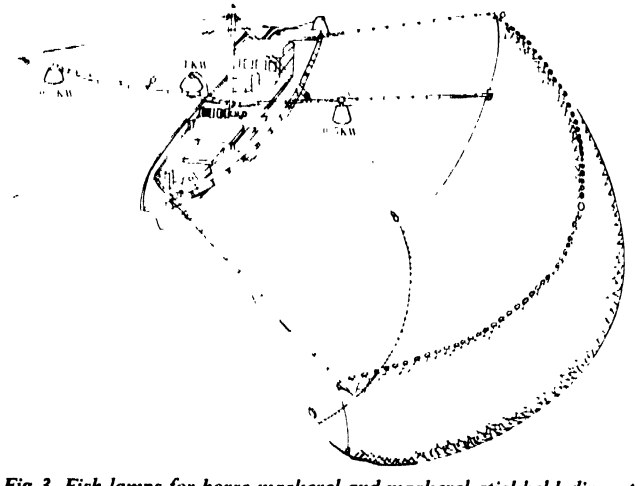


Fig 3. Fish lamps for horse mackerel and mackerel stickheld dip net fishing

Light attraction with bouke-ami net for mackerel and horse mackerel

Bouke-ami fishing (fig 3) with fish lamps is effectively carried out off the Central Pacific Coast of Japan.

The boats are 2–4.9 t with 26–45 hp diesel engines and have DC 105 V, 3 kW generators (few AC generators are used).

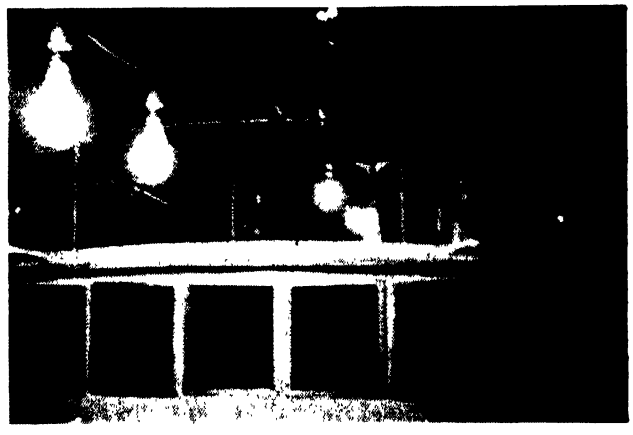


Fig 4. Fish lamps for cuttlefish angling boat

Fig 5. Auto-line hauler for cuttlefish angling boat

As shown in fig 3 ordinary anchors or sea anchors are cast and fish lamps (1 kW) fixed to starboard are switched on to attract fish detected with the help of fish finding equipment. After fish have been attracted, the anchor ropes are shifted from the bow to the central starboard side to position the boat broadside to the current. Then a fish lamp (0.5 kW) on the starboard side is turned on and the other lamps (1 kW) are switched off. From the portside the net is lowered while the lamp (0.5 kW) on the starboard side is dimmed. The net is hauled up when fish have densely crowded above the net under another 0.5 kW lamp on portside. The fishing grounds are usually about 15 m in depth.

LIGHT ANGLING FOR CUTTLEFISH

Cuttlefish fishing takes place mainly in the northern part of Japan in the Tohoku and Hokkaido areas. The fishing boats are 28–98 GT and employ about ten incandescent lamps (each 1,000 W) which hang on a line between the fore and aft masts (fig 4).

The number of fish lamps per boat is regulated by prefectural fishery law. As for the generators, two-thirds are AC and one-third are DC.

Average specification of boats and equipment are as follows:

gross tonnage	37	40	65	76	85
hp of main engines	160	210	220	250	320
capacities of generators for fish lamps kVA	30	30	40	40	40
number of bulbs fore (fore)	4	4	6	4	6
and aft of the bridge (aft)	6	6	6	8	8
number of fish lamps	10	10	12	12	14
height of fish lamps (m)	4.3	4.4	4.0	4.0	4.4

The cuttlefish is lured up from deep water by the lights, the intensity of which is not changed. The length of the angling lines is decided according to fishing conditions but is usually between 50 and 100 m. If the hooking rate is high, the boat will stay on the fishing ground for 4–6 hours. The cuttlefish lines are operated by automatic angling machines (fig 5).

Les techniques de pêche à la sardine et au thon sur les côtes françaises de Méditerranée

M. Bonnet

Fishing techniques for sardine and tuna on the French Mediterranean coast

The French Mediterranean coast is in general rich in pelagic fish: the bluefin tuna appears there for a great part of the year and sardine is particularly abundant in the Gulf of Leon. The fishery for these two species, and in particular for sardine, has developed considerably during the last years. The descriptions of the purse seines for sardine and tuna as well as of the purse seine vessels show that these fisheries still maintain a certain artisanal character. Their real modernization will require the introduction of new vessels at the same time.

Technicas empleadas en la pesca de la sardina y el atun en la costa Mediterránea Francesa

La costa Mediterránea Francesa es, en general, rica en especies pelágicas: el atún rojo o de aleta azul se encuentra en ella gran parte del año y la sardina es especialmente abundante en el Golfo de León. La pesquería de ambas especies, en particular la de la sardina, ha experimentado una considerable expansión en los últimos años. La descripción de las redes de cerco y de los barcos dedicados a la pesca de la sardina y el atún con redes de cerco muestra que ambas pesquerías conservan aún cierto carácter de artesanía. Para modernizarlas realmente será preciso introducir nuevas embarcaciones.

LA Méditerranée est généralement considérée comme une mer pauvre en ressources halieutiques. Si cette réputation est fondée pour ce qui est des espèces benthiques, le plateau continental étant le plus souvent très réduit et les conditions naturelles de milieu convenant peu au développement des animaux de fond, il en est tout autrement en ce qui concerne les poissons pélagiques, en particular dans les régions où les apports fluviaux sont importants comme c'est le cas, par exemple, dans le golfe du Lion. En effet, ce secteur, influencé par le Rhône et par d'autres fleuves de moindre importance, offre des conditions hydrologiques et biologiques très favorables aux poissons bleus: sardine surtout, thon, anchois, maquereau et sprat.

Cette richesse en espèces pélagiques fut longtemps ignorée, du moins sous-estimée. Ce n'est qu'à partir de 1961 que son exploitation a été développée grâce â l'utilisation des seines et à l'extension de l'emploi des appareils détecteurs ultra-sonores. Les chiffres de production montrent combien cette évolution a été importante. En effet, pour l'ensemble des côtes françaises de Méditerranée, les apports n'étaient que de 2 à 3000 tonnes par an avant 1961, c'est-à-dire à l'époque de la pêche aux filets maillants. Cette année ils dépassent 25.000 tonnes, dont plus de 20.000 de sardine et 1.500 environ de thon.

Les principaux centres producteurs sont Port-Vendres, Sète et Marseille, auxquels correspondent trois secteurs marins peuplés par des populations de sardines obéissant, dans leurs migrations, à une évolution différente des conditions de milieu. Il en résulte que les campagnes sardinières de ces trois secteurs sont décalées dans le temps, la pêche s'échelonnant presque toute l'année sur l'ensemble des côtes françaises.

Pour le thon rouge, ces côtes ne sont pas seulement

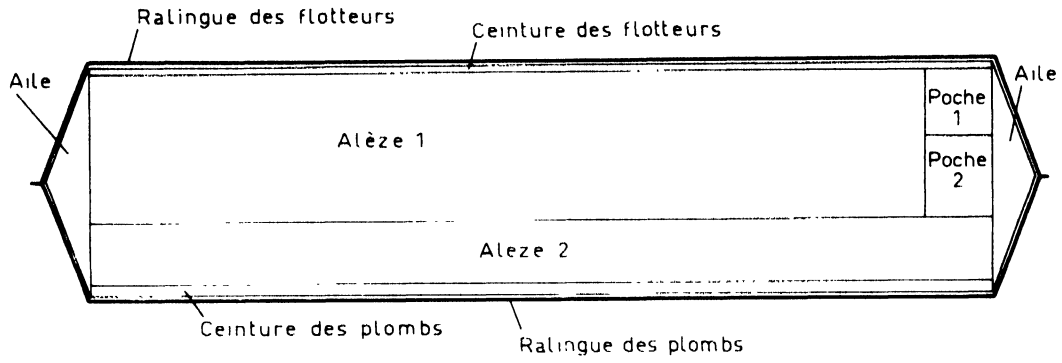


Fig 1. Schéma de montage d'une seine à sardine de 345 m de ligne de flottaison

TABLEAU 1. CARACTÉRISTIQUES DES DIFFERENTES PARTIES D'UNE SEINE À SARDINE
(voir schéma de montage fig 1)

	Longueur mailles étirées (m)	*Nb de mailles en longueur*	*Nb de mailles en hauteur*	*Grandeur du côté de la maille (mm)*	*Grosseur du fil (m/kg)*
Ralingue des flotteurs	345				
Ceinture des flotteurs	352	12.570	30	14	2.220
Alèze 1	336	16.800	4.000	10	13.400
Alèze 2	372	15.500	1.500	12	6.660
Poche 1	26	1.300	1.000	10	4.440
Poche 2	26	1.080	2.500	12	10.000
Ceinture des plombs	375	5.360	30	35	600
Ralingue des plombs	375				

un lieu de passage. Il s'avère, en effet, que ce poisson peut être présent dans le golfe du Lion, où il trouve une nourriture abondante, de l'été à la fin de l'hiver. Bien sûr, la fréquence et l'abondance de ce grand migrateur varient suivant les années. Dès le début de l'été et jusqu'en automne on le trouve également dans le golfe de Gênes et sur les côtes provençales. Le thon blanc ne fréquente que cette région orientale, en particulier en août et septembre; il est essentiellement capturé aux lignes traînantes, sa dispersion ne permettant pas le plus souvent l'utilisation de la seine.

Le but de ce rapport est de décrire quelles sont les techniques utilisées actuellement pour la pêche de ces espèces pélagiques. Ces techniques, bien qu'à l'origine de l'évolution spectaculaire de la production, revêtent encore un aspect artisanal et sont à perfectionner.

La seine à sardine

Les filets tournants et coulissants utilisés sur les côtes françaises de Méditerranée pour la pêche de la sardine présentent quelques différences suivant les navires. Ces différences concernent surtout les dimensions, toutes les seines ayant le même schéma général de montage. La description d'un filet de grandeur moyenne est la suivante (fig 1).

Flotteurs. Les flotteurs sont en chlorure de polyvinyle. De forme ovale, ils mesurent 9 cm de long et ont une flottabilité de 200 g pièce. Il y a un flotteur tous les 20 cm de ralingue au-dessus de l'alèze 1; ce nombre est en général doublé au niveau de la poche. La flottabilité totale est donc de l'ordre de 370 kg.

Ralingue des flotteurs. Elle est constituée par deux câbles en nylon:

Un câble de 5 mm de diamètre sur lequel sont enfilés les flotteurs,

Un câble de 3 mm de diamètre qui sert de ralingue de montage pour l'alèze de ceinture.

Ces câbles se prolongent jusqu'aux extrémités des ailes. Dans le cas du filet décrit, la longeur de la ligne de flotteurs est de 345 m, dont 320 m correspondent à l'alèze 1 et 25 m à la poche.

Ceinture des flotteurs. L'alèze de ceinture, appelée "cadenette", est en fil nylon câblé de 2.220 m/kg; ses mailles ont 14 mm de côté. Elle est montée avec 2% de flou[1] sur les 345 m de ralingue, ce qui lui donne une longueur de 352 m, mailles étirées. Sa hauteur est de 30 mailles.

Alèze 1. Cette nappe est en fil nylon câblé de 13.400 m/kg avec des mailles de 10 mm de côté. Son flou est de 3% par rapport à la ralingue des flotteurs. Elle a 16.800 mailles de long et 4.000 mailles de haut.

Poche. La poche se situe dans le prolongement de l'alèze 1; son côté supérieur correspond à 25 m de ralingue. Elle comprend deux parties dont les caractéristiques sont les suivantes:

poche 1: fil nylon câblé 4.440 m/kg mailles 10 mm de côté, 1.000 mailles de haut,

[1] Le taux d'armement correspondant, exprimé selon les recommandations de l'ISO, serait égal à 98% (longueur de ralingue/longueur du filet étiré).

poche 2: fil nylon câblé 10.000 m/kg mailles 12 mm de côté, 2.500 mailles de haut.

Ces deux parties de poche sont montées horizontalement avec 1 % de flou sur la ceinture, soit 3 % par rapport à la ralingue. Leur hauteur totale est égale à celle de l'alèze 1, soit 80 m mailles étirées.

Alèze 2. Cette pièce a 1.500 mailles en hauteur et 15.500 en longeur (mailles de 12 mm, fil de 6.660 m/kg). Son coefficient de flou est de 3 % par rapport à l'alèze 1 et au côté inférieur de la poche; sa longueur, mailles étirées, est donc supérieure de 8 % à celle de la ralingue des flotteurs.

Ceinture des plombs. La ceinture inférieure est montée avec seulement 1 % de flou sur l'alèze 2. Le fil est fort (600 m/kg), le côté des mailles mesure 35 mm. Comme pour la ceinture des lièges il y a 30 mailles en hauteur.

Ralingue des plombs. La ralingue des plombs, comme celle des flotteurs, se prolonge jusqu'aux extrémités des ailes; elle est en câble nylon de 8 mm de diamètre. Le montage ceinture-ralingue se fait raide à raide, c'est-à-dire que la longueur de la ralingue comprise entre les ailes est égale à celle de la ceinture, mailles étirées, soit 375 m.

Plombs. Les plombs pèsent 140 g pièce. Un lest de 360 kg est réparti sur les 375 m de ralingue, le nombre de plombs au mètre étant légèrement supérieur côté poupe.

Ailes. Les deux ailes sont identiques. Faites en fil de 730 m/kg, elles ont 400 mailles en hauteur et 20 mailles en longueur (mailles de 60 mm).

Anneaux et coulisse. Les anneaux, au nombre de 50, ont 20 cm de diamètre; ils sont en fer rond de 16 mm. Pour favoriser le coulissage, la hauteur des pattes d'oie qui servent à pendre les anneaux sur la ralingue diminue des extrémités du filet (1,5 m) vers le centre (1 m).

La coulisse est un câble en polypropylène de 30 mm de diamètre comportant 4 torons à âme de plomb. Sa longueur totale est de 450 m; elle pèse 650 g au mètre.

Les caractéristiques des différentes alèzes sont résumées dans le tableau 1. Il est à remarquer que le sens du filet est toujours parallèle aux ralingues, c'est-à-dire qu' une traction exercée sur chacune des nappes dans le sens horizontal tend à resserrer les noeuds des mailles.

Ce filet type est appelé "lamparo" parce qu'utilisé uniquement de nuit, le poisson étant attiré avec des lampes. Comme nous l'avons déjà dit, les différences que peut présenter la seine d'un navire par rapport à celle d'un autre concernent essentiellement les dimensions. Ainsi, la longueur de la ralingue des lièges varie de 320à 390 m et la hauteur totale du filet de 100 à 150 m pour l'ensemble des "lamparos" des côtes françaises de Méditerranée.

Une variante intéressante est à signaler: il s'agit de la seine à sardine utilisée de jour ou même de nuit mais sans attraction lumineuse. Ce filet, appelé localement "alachare" est plus long, moins haut, en mailles plus grandes et en fils plus forts que les "lamparos". Ses principales caractéristiques sont les suivantes:

alèze 1: fil 6.660 m/kg, mailles 12 mm, 2.000 mailles de haut,
alèze 2: fil 4.440 m/kg, mailles 13 mm, 1.000 mailles de haut.

La seine à thon

Sur les côtes françaises de Méditerranée, les filets tournants et coulissants à thon sont, à peu de chose près, tous du même type. Ils se différencient surtout par leurs dimensions qui sont fonction de l'importance des navires. A titre d'exemple, voici quelles sont les caractéristiques d'un filet ayant 800 m de ligne de flottaison (fig 2).

Ralingue des flotteurs. La ralingue supérieure est un câble en nylon de 8 mm de diamètre sur lequel sont enfilés les flotteurs. Elle se prolonge jusq'aux extrémités des deux ailes. Le montage des alèzes se fait directement sur cette ralingue, sans ceinture.

Flotteurs. En résine synthétique et de forme ovale, les flotteurs ont une longueur de 145 mm et un diamètre de 85 mm. Leur flottabilité est de 810 g pièce. Il y en a trois par mètre de ralingue, sauf au niveau de la poche où ils sont plus nombreux (4 par mètre). La flottabilité totale est d'environ 2 tonnes.

Alèzes. Le filet est constitué par cinq alèzes juxtaposées dans le sens de la longueur et montées sur la ralingue avec 5 % de flou. Ainsi, pour une longueur de ligne de flottaison de 800 m on a une longueur totale de nappe de 840 m, mailles étirées, la hauteur étant de 95 m.

Le tableau 2 donne la grosseur du fil, le nombre et la grandeur des mailles, pour chacune des pièces constitu-

TABLEAU 2. CARACTÉRISTIQUES DES DIFFERENTES PARTIES D'UNE SEINE À THON
(voir schéma de montage fig 2)

	Longueur mailles étirées (m)	*Nb de mailles en longueur*	*Nb de mailles en hauteur*	*Grandeur du côté de la maille (mm)*	*Grosseur du fil (m/kg)*
Ralingue des flotteurs	800				
Alèze 1	350	1.840	500	95	730
Alèze 2	200	1.110	530	90	600
Alèze 3	100	665	635	75	600
Alèze 4	80	535	635	75	400
Alèze 5 haut	80	670	790	60	400
Alèze 5 bas	110	915			
Poche	30	250	335	60	180
Ceinture des plombs	850	12.145	70	35	600
Ralingue des plombs	850				

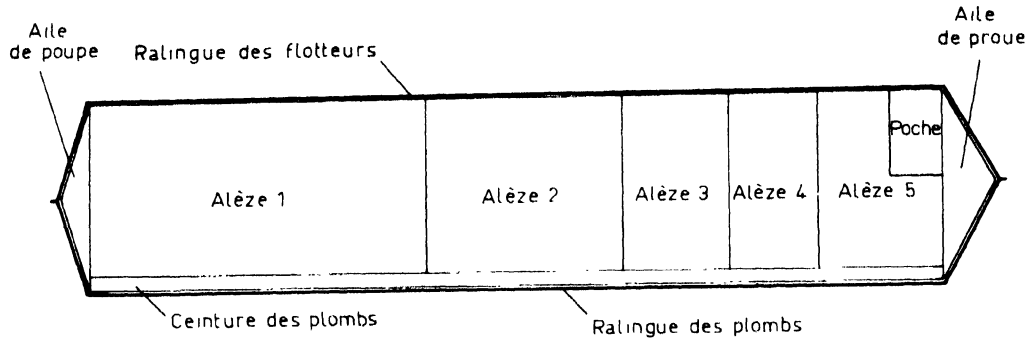


Fig 2. Schéma de montage d'une seine à thon de 800 m de ligne de flottaison

tives du filet. Précisons que tous les fils sont en nylon tressé et que les mailles des cinq alèzes sont dans le sens horizontal comme pour le filet à sardine.

Poche. La poche est incluse dans l'alèze 5 dont elle a la même grandeur de maille mais un fil plus fort. Elle mesure 30 m de long sur 40 m de haut ce qui fait respectivement 250 et 335 mailles de 60 mm de côté. Elle est aussi montée avec 5% de flou sur la ralingue.

Ceinture des plombs. La ceinture est cousue presque raide à raide sur l'ensemble des nappes puisqu'elle mesure 850 m de longueur totale, mailles étirées, ce qui représente un flou de l'ordre de 1% par rapport aux alèzes, soit 6% par rapport á la ralingue des flotteurs.

Ralingue des plombs. Cette ralingue est un câble de nylon de 10 mm de diamètre. La "cadenette", ou ceinture, est montée raide sur ce cordage qui a, aussi, 850 m de long.

Plombs. Les plombs, identiques à ceux du lamparo, sont répartis sur la ralingue à raison d'1 kg par mètre ce qui représente un lest total de l'ordre de 850 kg. D'une manière générale la répartition n'est-pas uniforme: on charge davantage dans la partie du filet opposée à la poche (côté poupe). Il est à remarquer que certains pêcheurs utilisent une chaîne continue à la place des plombs.

Ailes. L'aile de proue, située près de la poche, a une longueur de 8 m et une hauteur égale à celle des alèzes: 95 m. Les mailles sont dans le sens horizontal; elles ont 110 m de côté et sont faites en fil de 400 m/kg.

L'aile de poupe a des caractéristiques identiques mais elle ne mesure que 4 m de long.

Anneaux et coulisse. Les anneaux sont les mêmes que ceux du "lamparo"; il y en a un tous les 10 m de ralingue des plombs soit 85 au total pour le filet décrit. Les pantoires, en forme de patte d'oie, sont en câble de nylon de 14 mm de diamètre. Leur longueur décroît des extrémités du filet (2 m) vers le centre (1,5 m), ceci pour faciliter le coulissage.

La coulisse est la même que celle utilisée pour la seine à sardine: polypropylène 4 torons à âme en plomb. Ce matériau est préférable à celui employé auparavant (4 torons manille armés d'acier) parce qu'il ne rouille pas et qu'il est très souple. La solidité est assurée par un diamètre légèrement supérieur: 30 mm pour le polypropylène armé de plomb au lieu de 28 mm pour le câble mixte manille-acier.

Ce filet tournant et coulissant à thon, appelé localement "seinchole", est d'une construction très simple ce qui présente un advantage appréciable. En Méditerranée française les "seincholes" ont, suivant la puissance des navires, une longueur de ligne de flottaison qui varie de 600 à 1.000 m et une hauteur de nappe de 70 à 140 m. Le filet décrit peut être manoeuvré par un bateau de 17 m de long et de 200 cv de puissance.

Les seineurs polyvalents sardiniers-thoniers

Depuis 1960 on assiste à une transformation progressive de la flottille de pêche des poissons pélagiques. En effet avant cette date, c'est-à-dire avant la généralisation de l'emploi des "lamparos", la pêche à la sardine aux filets maillants était l'oeuvre de petits bateaux du type "catalane" dépassant rarement 12 m de longueur et d'une puissance de 40 à 75 cv. Ces embarcations, utilisées quelques temps encore pour le filet tournant, furent rapidement remplacées par des untités de plus fort tonnage: d'abord des chalutiers s'armèrent à la seine pendant la campagne sardinière, ensuite de nouveaux navires furent spécialement construits pour travailler uniquement au filet tournant.

Par ailleurs, l'évolution de la pêche du thon ayant suivi de prês celle de la sardine, les sardiniers devinrent également thoniers, à l'exception de quelques rares bateaux parmi les plus petits. Cette orientation vers le seineur polyvalent s'est accentuée depuis peu par le fait que bon nombre de chalutiers restent maintenant armés toute l'année pour le travail à la seine.

Caractéristiques générales. Les seineurs sardiniers-thoniers les plus répandus surles côtes françaises de Méditerranée ont les caractéristiques suivantes:

matériau de construction: bois
longueur: 16 à 18 m
largeur: 4,5 à 5,5 m
puissance: 180 à 250 cv
tonnage: 15 à 25 tx.

Les navires de construction récente sont plus grands (20 à 25 m) et plus puissants (400 à 600 cv). Ils sont tous en bois.

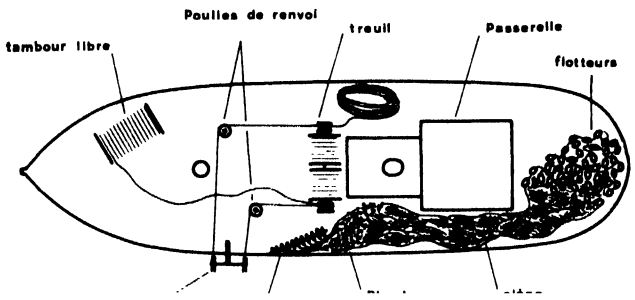


Fig 3. Plan d'aménagement d'un seineur sardinier-thonier

Aménagement. La majorité des sardiniers-thoniers étant des chalutiers reconvertis ou encore en activité, leur aménagement répond davantage aux conditions de travail au chalut plutôt qu'au maniement de la seine. En effet, cet aménagement est en général le suivant (fig 3).

La passerelle est placée vers l'arrière du bateau. Le filet ne peut donc être disposé à bord que sur le côté: les lièges sur l'arrière, les plombs sur l'avant.

Le treuil est situé devant la passerelle. Prévu à l'origine pour le chalutage, il est muni de deux bobines et de deux poupées; seules les poupées sont utilisées pour virer la coulisse.

La potence de seine est placée vers l'avant, en général du côté babord, au niveau de deux poulies de renvoi qui se trouvent en avant des deux poupées du treuil.

Enfin, ces navires, conçus à l'origine pour effectuer des sorties journalières comme tous les chalutiers méditerranéens, ne disposent d'aucun aménagement particulier pour loger et nourrir l'équipage. Si ceci n'est pas un handicap pour la pêche sardinière, il n'en est pas de même pour les campagnes thonières qui se déroulent souvent loin du port d'attache.

Les nouvelles unités construites spécialement pour la pêche à la seine sont aménagées différemment. D'une manière générale le travail se fait sur la plage arrière qui est bien dégagée, les superstructures étant placées à l'avant comme sur les clippers américains. De plus, ces nouveaux bateaux offrent à l'équipage un certain confort pour les campagnes lointaines de longue durée et ont en général une cale réfrigérée.

Equipement des seineurs

Seine à sardine. L'équipement d'un seineur armé pour la pêche à la sardine comprend les appareils suivants (fig 3).

Treuil. Comme nous l'avons déjà dit, cet engin est le plus souvent un treuil de chalutage qui est placé dans le sens de la largeur du bateau. L'utilisation de ses deux poupées pour la seine rend donc obligatoire l'installation de deux poulies de renvoi.

Potence (fig 4). Placée sur le côté et sur l'avant du navire, en face des poulies de renvoi, la potence est rabattable sur le pont ce qui facilite la mise à bord des anneaux. Elle est munie de deux poulies coupées dans lesquelles passe la coulisse.

Râtelier à anneaux (fig 4). Fixé sur la lisse, il se trouve entre la potence et l'emplacement des plombs du filet.

Tambour libre (fig 5). Il s'agit d'une bobine, libre sur son axe, sur laquelle la coulisse est enroulée.

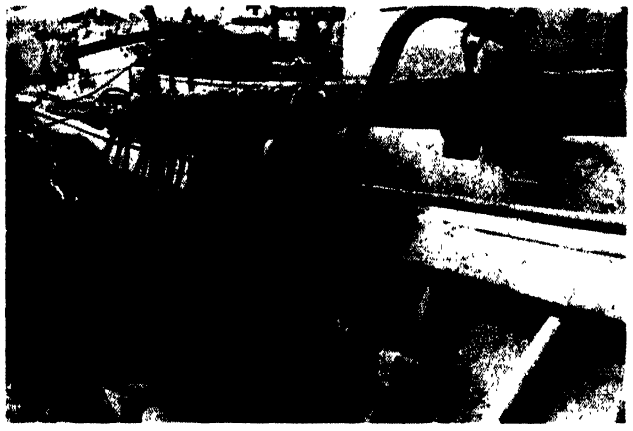


Fig 4. La potence et le ratelier a anneaux sur un seineur

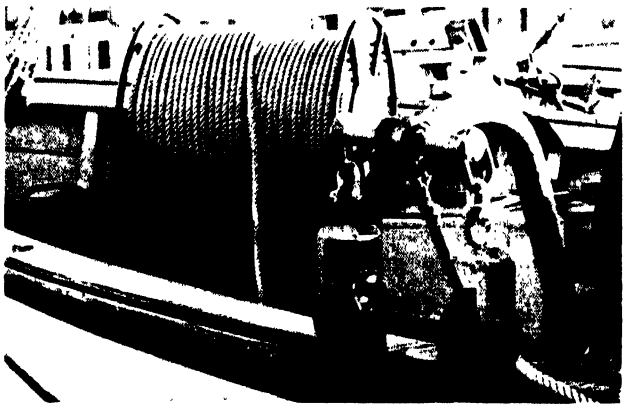


Fig 5. La bobine d'enroulement de la coulisse

Power-block. Son utilisation n'est pas courante en Méditerranée française, du moins pour les filets à sardine. Ceci tient surtout au fait que les patrons-pêcheurs préfèrent garder un équipage assez nombreux (8 à 10 hommes) pour que le traitement du poisson à bord (mise en caissettes) et son débarquement soient faits le plus rapidement possible.

Annexe "feu" (fig 6). Cette annexe, prise en remorque, est une petite embarcation en bois ou en matière plastique de 5 m de long équipée d'un groupe électrogène. Ce

Fig 6. Anexes "feu" utilisees par les sardiniers sur les côtes françaises de Méditerranée

groupe a une puissance motrice de 15 à 20 cv (moteur diésel); d'une manière générale il alimente cinq lampes de 1.000 W chacune, placées sous deux réflecteurs. Pour éviter que les vibrations du moteur ne se transmettent dans l'eau et gênent la concentration du poisson sous les lampes, le groupe électrogène n'est pas fixé à la coque: il est simplement posé sur des pneus dans le fond de la barque.

Sondeur. Tous les navires sont équipés d'un sondeur enregistreur à ultra-sons. Cet appareil, installé dans la passerelle, sert au repérage des bancs de poissons. Il a une fréquence moyenne de 40 à 45 kHz.

Seine à thon. A l'exception de l'annexe "feu" et du sondeur, tous les appareils qui viennent d'être décrits sont également utilisés pour la seine à thon dans les mêmes conditions que pour celle à sardine.

En plus de cet équipement, un navire armé à la "seinchole" possède une annexe. C'est une petite embarcation de 4 à 5 m de long, en bois ou en matière plastique. Elle est le plus souvent actionnée à la rame, parfois elle possède un moteur hors-bord de 20 à 40 cv.

Pour ce qui est du power-block, son utilisation tend à se généraliser pour la pêche du thon. Cet appareil permet de caler le filet plusieurs fois par jour avec un équipage relativement réduit, sans fatigue excessive pour ce dernier. Il est à noter que cette poulie est maintenant installée de préférence sur une grue hydraulique orientable.

OPERATIONS ET TACTIQUES

La pêche à la sardine s'effectue essentiellement de nuit, le poisson étant attiré à la lumière artificielle. Cette technique n'est pas efficace aux époques de pleine lune. Les différentes opérations qu'elle requiert sont, chronologiquement:

Repérage au sondeur des zones de concentration de sardine,

Mise en place et en fonction de l'annexe "feu" au-dessus des bancs,

Encerclement de l'annexe avec la seine lorsque le poisson est suffisamment concentré sous les lampes,

Fermeture basse du filet et mise à bord.

La durée de l'attraction à la lumière varie suivant la position et la densité du poisson lesquelles sont fonction des conditions de milieu; elle est en moyenne de 4 à 6 heures. Il y a peu de temps encore, deux annexes "feu" étaient utilisées par un même seineur, ceci afin d'éviter les conséquences d'une panne éventuelle d'un groupe électrogène et de multiplier les chances de capture. L'expérience a montré que l'amploi d'un seul canot à autant d'efficacité, de plus les risques de panne sont maintenant très faibles avec les moteurs marins diésels.

Un pêcheur expérimenté peut estimer d'une manière assez précise le tonnage des sardines attirées sous les lampes à l'examen de l'échogramme du sondeur. En général, l'encerclement a lieu juste avant le lever du jour, moment le plus favorable à la concentration du poisson. Cette opération se fait sans hâte (vitesse: 3 à 5 noeuds) de même que la fermeture basse du filet à l'aide de la coulisse.

Contrairement au filet "lamparo", la seine du type "alachare" est utilisée sans attraction lumineuse, de nuit comme de jour. Cette technique n'est practiquée que durant la belle saison lorsque le poisson est très abondant par petits fonds (15 à 30 m), en particulier dans la région de Sète. Dans ces conditions, le filet est calé sur détection.

Pêche au thon

Le repérage du poisson se fait uniquement à la vue. Lorsqu'une compagnie de thons est aperçue, le navire fait route sur elle et l'encercle avec la seine de manière à ce que l'action du courant ou du vent ait tendance à l'éloigner du filet lorsque le cercle est fermé.

Le rôle de l'annexe est de maintenir l'aile de proue dès sa mise à l'eau, ce qui permet de fermer le cercle plus vite. La vitesse d'encerclement est de l'ordre de 8 à 10 noeuds. Contrairement à ce que pensent certains pêcheurs, il convient de ne pas virer trop précipitamment la coulisse pour fermer les anneaux. En tous cas, l'expérience a souvent montré qu'il était préférable, avant de virer, de laisser le temps nécessaire aux plombs et aux anneaux d'atteindre leur profondeur maximale d'immersion.

Il arrive parfois qu'un seineur emprisonne une quantité de thon trop importante pour la résistance de son filet; dans ce cas il fait appel à un autre navire qui encercle à son tour le poisson.

CONCLUSIONS

Le développement important de l'exploitation des espèces pélagiques sur les côtes françaises de Méditerranée, en particulier de la sardine et du thon, est encore trop récent pour avoir permis une modernisation et une spécialisation suffisantes des techniques. En effet, la production est dans sa majeure partie assurée par des chalutiers anciens et de faible tonnage armés en seineurs périodiquement ou, depuis peu, toute l'année. Ces navires utilisent, suivant les saisons, soit la seine à thon, soit la seine à sardine, filets caractérisés par leur simplicité de construction.

Quoi qu'il en soit, ces moyens techniques sont somme toute efficaces et d'une bonne rentabilité puisque 10 tonnes de sardines sont fréquemment pêchées en un coup de filet et que, pour le thon, une seule pêche peut atteindre 50 tonnes.

Quelques nouveaux navires, de construction récente, donnent un aspect de ce que pourrait être l'avenir. Il s'agit de bateaux plus grands et plus rapides, spécialement conçus pour le travail à la seine, en particulier pour le thon, dont les aménagements pour l'équipage et les installations frigorifiques permettent d'effectuer des sorties de longue durée. Une tendance semble d'ailleurs s'affirmer: certains de ces nouveaux navires se consacreraient uniquement aux campagnes thonières.

Cette orientation vers une spécialisation des armements, de même que le retard dans la modernisation des techniques, sont certainement dus en partie aux difficultés d'écoulement des apports en sardine, la commercialisation n'étant pas encore à l'échelle de la production.

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Clupeid Fisheries in the Tropical Eastern Atlantic

P. Dykhuizen and M. Zei

Les pêches de clupéidés dans l'atlantique tropical oriental

Les pêches de clupéidés au large de la côte ouest de l'Afrique centrale, de la Mauritanie au Congo, ont une importance qui s'accroît. Au cours de la dernière décade une assistance technique a été apportée à plusieurs pays de cette région. Les pirogues ont été motorisées et les filets maillants d'encerclement ont été remplacés par des seines coulissantes à maillage plus petit. La présence, ou l'absence, de remontées d'eau froide détermine parfois la visibilité du poisson en surface. L'emploi d'un équipement de détection acoustique du poisson a montré que les stocks de clupéidés abondaient par moment mais ne pouvaient apparaître en surface du fait de températures d'eau trop élevées. Ceci est particulièrement vrai pour *Sardinella aurita*. *Sardinella eba* supporte plus facilement les plus hautes températures. La région est exploitée également par plusieurs pays étrangers employant de modernes chalutiers à pêche arrière, seineurs et navires-mères, qui viennent s'ajouter aux pirogues locales. Depuis 1964 plus de 100 seineirs de construction locale ont joint cette pêcherie. La plupart d'entre eux ont des treuils à entraînement hydraulique, mais pratiquement pas de power blocks. Cinq pour-cent seulement de la flottille ont des échosondeurs, mais ce pourcentage est en augmentation. L'emploi de l'attraction par la lumière pour la pêche à la seine coulissante de nuit est intéressant en dehors de la saison d'upwelling. Des captures importantes au chalut ont été signalées par l'URSS vers la fin des années 50 dans les profondeurs de 60 à 150 m. Des captures similaires ont été effectuées en 1966 et 67. De nombreux navires se sont convertis au chalutage pélagique à longueur de journée, les meilleures prises étant faites de nuit. Sur vingt chalutiers à pêche arrière ghanéens, dix utilisent maintenant le chalut pélagique.

Pesquerías de clupeidos en el atlantico oriental tropical

Cada vez son más importantes las pesquerías de clupeidos de la costa occidental del Africa central, desde Mauritania hasta el Congo. Durante el último decenio se ha prestado asistencia técnica a los varios países de la región. Se ha dotado de motores a las canoas y las redes de enmalle circulares se están sustituyendo por redes de cerco de jareta de malla más pequeña. La emergencia de aguas frías, o la carencia deésta, determina a veces que los peces se puedan observar o no sobre la superficie. El empleo de equipo acústico para localizar los peces ha demostrado que las poblaciones de clupeidos abundan en ocasiones pero que no pueden salir hasta la superficie a causa de la excesiva temperatura del agua. Asi ocurre especialmente en lo que se refiere a *Sardinella aurita*. En cambio *Sardinella eba* tolera mejor las temperaturas más elevadas. En la zona pescan también muchos países extranjeros que cuentan con arrastreros modernos de pesca por la popa, cerqueros y barcos nodriza, además de canoas locales. Desde 1964, más de 100 barcos para la pesca de cerco construidos en la región han entrado a participar en la pesquería. Casi todos ellos están dotados de maquinillas accionadas hidráulicamente, pero prácticamente no tienen poleas mecánicas. Sólo el 5 por ciento de la flota poseen ecosondas, aunque esta porcentaje está aumentado. La atracción con luz utilizando redes de cerco de jareta de noche es útil fuera de la epoca de afloramiento de aguas profundos. La U.R.S.S. ha informado que a finales del decenio de 1950, en profundidades de 60 a 150 metros, se lograron grandes capturas utilizando artes de arrastre. Capturas analogas se lograron en 1966 a la profundidad de 67 m. Muchos barcos están cambiando sus actividades dedicándose ahora a pescar al arrastre entre dos aguas durante todo en día, realizando mejores capturas por la noche. Diez de los veinte grandes arrastreros de Ghana que pescan por la están utilizando ahora redes para pescar entre dos aguas.

THIS review principally covers the clupeid fisheries along the eastern central Atlantic from Mauritania to the mouth of the Congo River, but some mention is also made of areas to the north and south of the region (fig 1).

Ghana is particularly stressed. First, Ghanaian fisheries have been developing progressively without much foreign assistance. They should be considered as predominantly African and thus give a good example of how the indigenous fisheries can successfully develop to a modern stage. Fishing has expanded beyond the range of national waters in spite of many economic difficulties. Secondly, Ghanaian fisherman can be found all along the central West African Coast, introducing his own gears and methods of fishing, thus strongly influencing the fisheries of the countries concerned, especially in Sierra Leone and Guinea. Ghanaian fisheries are even far ahead of Senegal, with its very rich fishing grounds. New gears and fishing techniques have easily been implemented by Ghanaian fishermen. Thirdly, in Ghana there is also much understanding of and collaboration with fisheries sciences, which have been developing here during the last decade as an African activity under the encouragement of the Technical Assistance of the United Nations and its agencies. The Marine Fisheries Research Unit in Ghana is a natural follow-up in progressive fisheries development.

BIOLOGICAL AND OCEANOGRAPHIC BACKGROUND

There are principally two clupeids, *Sardinella aurita* and *S. eba*, of great economic importance in the east-central Atlantic from Mauritania to Angola. The first species seems far more abundant and commercially more important, especially off Senegal, Ghana and south of Gabon.

Sardinella aurita is primarily found and fished in areas with a well-formed coastal upwelling (fig 2). There is a considerable fall of temperature in the surface layers, which may be seasonal or permanent. These regions are: off Senegal as far south as Cape Vergas (mainly from December to June); off Ivory Coast and Ghana from Cape Palmas as far east as Lome/Cotonou (from July to October) with a minor upwelling around January; off Gabon from Cape Lopez (July) and off Congo (May to December), Angola (practically all the year round) southwards to South Africa. Towards Morocco in the north and Angola in the south *Sardinella aurita* becomes gradually less abundant and eventually disappears. Here, a more or less permanent upwelling of cold water occurs and supports large pilchard fisheries off Morocco (*Sardina pilchardus*) and off south Angola-Nimibia (*Sardinops ocellata*). In the rest of the east-central Atlantic region, i.e. off Guinea, Sierra Leone and Liberia as well as off Nigeria and Cameroon no significant upwellings are

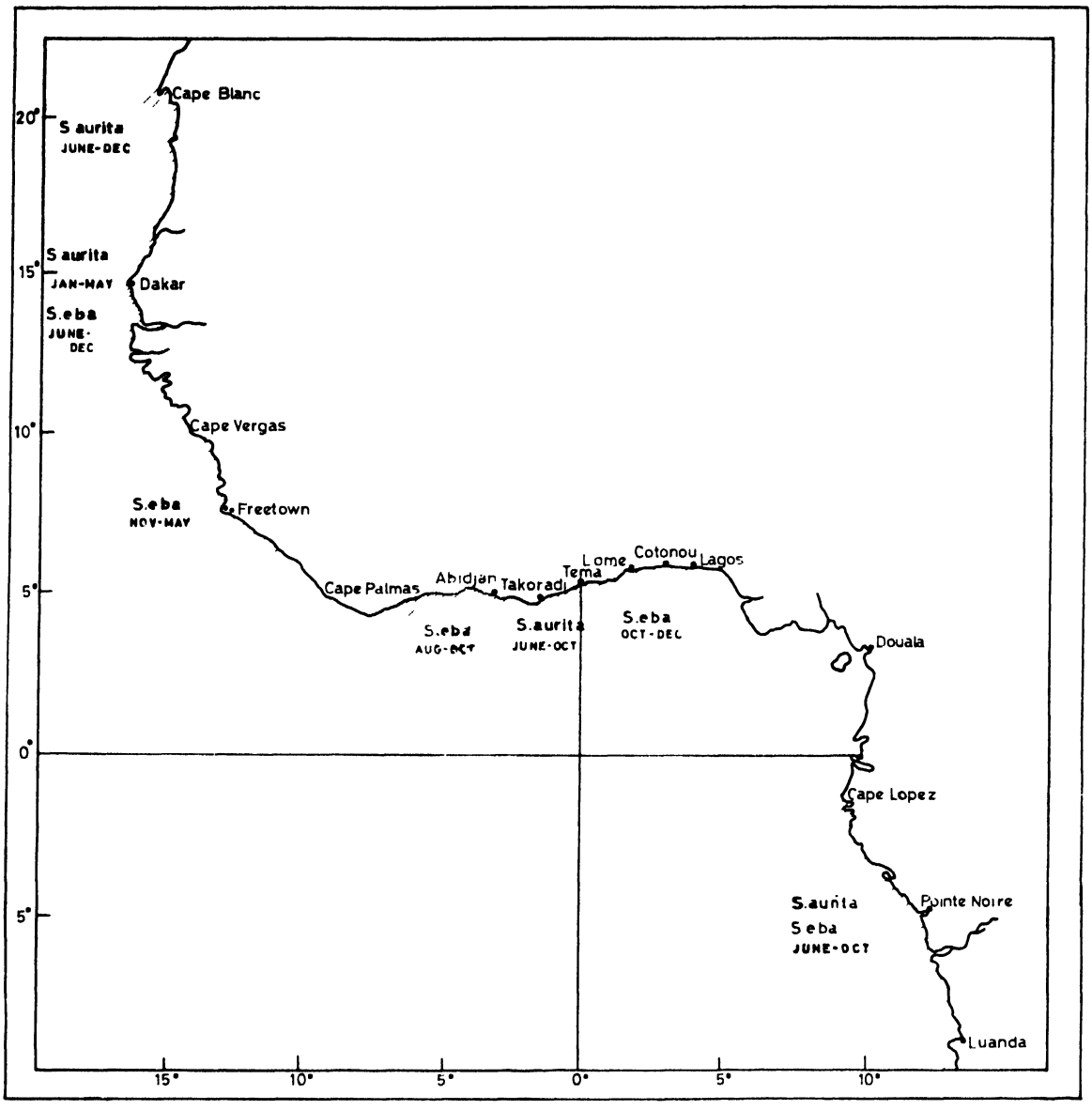


Fig 1. Main fishing grounds and fishing seasons in the tropical eastern Atlantic

known. Here schools of *Sardinella aurita*, seldom appear in the surface layers.

The main canoe fishing season for this fish is correlated with sea temperature below 25° C. The best catches by canoes are taken below 23° C. It is evident that the correlation between catch and temperature has to be interpreted as a restricted tolerance of this species to high temperature.

Distribution of *Sardinella eba* is less typical or restricted as it partly coincides with *Sardinella aurita* while in some areas which have no upwelling of cool waters, the species replaces *Sardinella aurita*. *S. eba* is tolerant of high temperatures. From the catch statistics as well as from the last results of the regional and national fisheries projects supported by UNDP and FAO it is apparent that the largest concentrations of *S. eba* are to be found off Ivory Coast, Sierra Leone and Gambia.

However, it should be pointed out that our knowledge of the distribution and, particularly, of the abundance of sardinellas in the east central Atlantic, is mainly based on fishery activity. Thus it is unknown whether sardinellas occur in large concentrations in those areas where there is at present no fishery or only minor fishing. Lack of catch does not necessarily mean non-availability. There are some indications of the occurrence of rather large concentrations of sardinellas off Sierra Leone and Guinea where at present there is practically no fishing. However, fishery survey (acoustic detection) has not found any indication of large sardinella stocks in these waters.

The greater part of local fishing for sardinellas is still a surface fishery. Fishing for *Sardinella aurita* takes place where and when the coastal upwelling of cool subthermocline water brings fish to the surface and near to the shore. In years of strong upwelling local fisheries, especially the canoes, are very successful with surrounding gillnets (Ali nets). When the coastal upwelling is weak canoe fishing for *S. aurita* is poor. Then motorized canoes having a greater operational range than the paddled canoes, have

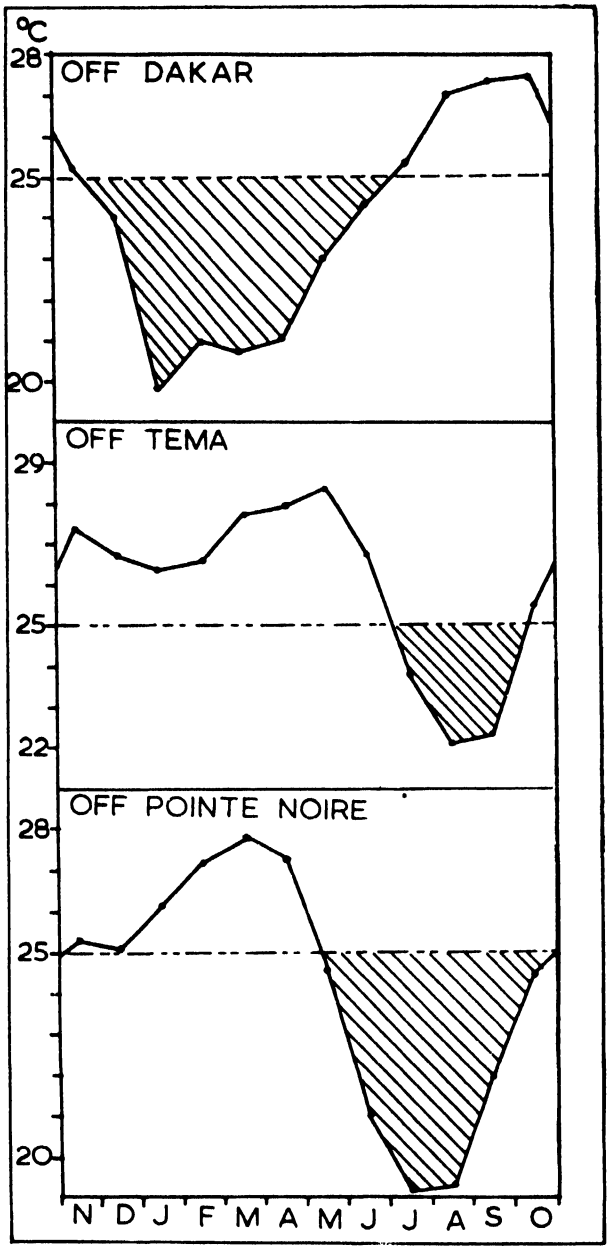


Fig 2. Annual mean temperature in the upwelling areas

relatively better catches. Purse seiners do not face the same situation as they can locate fish by acoustic fish finders and their fishing is to a lesser extent restricted to coastal upwelling season.

Sardinella eba can be caught on the surface more or less all year round in the non-upwelling area, as well as during the hydrographic stability characterized with a warm upper-thermocline layer in the areas with a seasonal upwelling. This explains why *Sardinella eba* is not vulnerable to bottom trawls fishing in rather cool layers.

Among related species the bonga, *Ethmalosa fimbriata* (taxonomically a clupeid) deserves special attention as it is of great economic importance in some parts of the east central Atlantic from the river Senegal to Sierra Leone, and along the coast of Nigeria, Cameroon and eastward to the mouth of the Congo. These areas, including the more isolated Abidjan region, are characterized by extensive estuarine regions enriched by river effluent. This fish occurs in the lagoons and estuaries as well as in the shallow sea at rather high temperature over 25° C. As fishing for bonga on the west African coast is carried out entirely by indigenous canoes with gillnets, these fisheries will not be further dealth with.

The anchovy *Anchoviella guinensis* which is at present neglected might, in the future, gain a considerable economic importance. A plankton survey off Ghana showed a great abundance of eggs and larvae of this species. There is so far hardly any fishing for anchovy; it is mainly caught when fishing for small sardinellas.

EXPLOITATION

Although the greatest potential resources are the stocks of *Sardinella*, it is difficult to estimate their present catch due to a lack of reliable statistics. Yearly production might vary from 100,000 to 150,000 t; it could possibly be increased to half a million metric tons by introducing new and more efficient fishing techniques and by increasing the fishing fleet. At present sardinellas are predominantly fished by purse seines from motor vessels as well as by encircling gillnets from canoes. Fishing with bottom and midwater trawls is still, in most areas, in its beginning. Future developments in fishing gear and methods offer good prospects of overcoming seasonal activity.

Sardinella is also important as bait for tuna live-bait fishing, which is the mainstay of the tuna fishing industry in the West African Atlantic and Japanese longline vessels have started using sardinellas as bait.

In the FAO Year Book of Fishery Statistics *Sardinella* and bonga are usually grouped as one item although some breakdown is given whenever possible. Unfortunately, there are no data on catches in Congo, Gabon, Cameroon and Guinea. In the figures for Nigeria Sardinellas play a rather neglible role, for here, as well as in Sierra Leone, the catch refers almost entirely to bonga (Table 1).

Fishing areas and catch

Mauritania is the first country of the northwestern African region, which is under the influence of the coastal upwelling—Casablanca in Morocco being approximately the northern border. Large schools of sardinellas and other pelagic fish have been observed although main fishing is on demersal fish stocks. Only recently fishing for sardinellas has increased, using purse seines and also midwater and bottom trawls. No reliable statistical data are available as fishing is mainly carried out by other nations. In addition to sardinellas, several other pelagic fishes are important, particularly carangids and scombrids.

The waters off Senegal are still within the northwest African upwelling and are abundant in both demersal and pelagic fish. The total landings vary but are steadily increasing from about 30,000 t in 1958 to about 150,000 t in 1969. Of this amount the local canoe fleet, partly motorized, landed approximately one half to two-thirds and the rest was caught by trawlers and purse seiners.

It is only lately that a reasonable industrial fishery for

TABLE 1. CLUPEID LANDINGS IN THE TROPICAL EASTERN ATLANTIC (IN 1,000 t)

	1967				1968				1969			
	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)
Angola	56.9	0.7		56.2	94.3	0.3		94.0				
Congo (Brazz)	1.7	1.7			1.7	1.7			2.2	2.2		
Ghana	43.2	43.2			12.2	12.2			24.4	24.4		
Ivory Coast	19.2	19.2			16.0	15.8	0.2		20.3	20.2	0.1	
Morocco	210.0			208.1	170.3			167.6				
Namibia	729.3			707.4	969.8			808.3				
Senegal	45.3	32.3	13.0	0	50.4	36.0	14.0	0	—	—	—	—
Sierra Leone	28.2	4.2	24.0		18.0	2.0	16.0		13.0	2.0	11.0	

(1) Total clupeids. (2) Sardinellas. (3) Bonga. (4) Pilchard. Data from FAO Yearbook of Fishery Statistics and personal communication.

Sardinella has been established. In previous statistics only combined catch data for *Sardinella* and bonga were given, figuring about 35,000 t in 1963. The first purse seiner started fishing for *Sardinella* in 1964 in Senegalese territorial waters. At present most industrial fishing is carried out by foreign, particularly French, enterprises, but recently the local fishing fleet has been gradually increasing.

Reliable observations reports show that large stocks of *Sardinella* and other pelagic fish are present on the wide shelf off Guinea, but local fisheries are rudimental. Present fishing fleet consists of a few hundred very small cutters (some motorized) and 1,000 to 1,500 relatively small canoes. It is estimated by Guinean authorities that the yearly catch might vary from 2,000 to 3,000 t although the country could easily absorb some 30,000 t of fish annually. Bonga is the prevalent species.

Fisheries in Sierra Leone depend at present primarily on canoe fishing for bonga. Their yearly catch was reported to reach about 15,000 t; only a small fraction of this is attributed to *Sardinella*. Lately, yearly production has dropped due to departure of Ghanaian fishermen. The catch by small local trawlers is negligible. There is a substantial import of demersal fish by large foreign trawlers, while tuna is mainly transhipped.

Commercial fishing for *Sardinella* has a promising future as there are rather large stocks. The current UNDP/SF Project recently reported in shallow coastal waters over 100 schools within a radius of a few miles, each estimated to range from 5 to 20 t. The prevailing species was *Sardinella eba*.

Sardinella schools (species not known) were reported off Liberia. Trawler landings of demersal fish overshadow those of bonga.

The waters off Ivory Coast, abounding in both *Sardinella* species, are considered, together with the Ghanaian waters, to be the best fishing areas in the Central Gulf of Guinea. Apart from a modern trawl fishery, bonga fishery and transhipment of tuna, the major fishing activity is concentrated on *Sardinella*. Besides the traditional canoe fisheries for *Sardinella* (restricted to the short upwelling season), a modern fleet of purse seiners, operated mainly by foreigners, is gradually developing and consists at present of approximately 40 units. In 1969 the catch of *Sardinella*, approximately 20,000 t, is one-third of total fish landings by the local fleet.

The Ghanaian marine fisheries are distinguished by the large yet insufficient exploitation of *Sardinella* stocks by canoes and purse seiners, and by the rapid increase of distant trawlers, fishing primarily for demersal fish. It is only recently that some of these trawlers have caught pelagic fish near the bottom or in midwater. However, the *Sardinella* fishery prevails but its paramount position has recently slightly declined.

The artisan canoe fishery for *Sardinella* continues to be important. Too few good harbours and long sandy beaches favour the canoes. Of a total fleet of 8,000 canoes, about 2,000, nearly all equipped with outboard motors, are engaged in *Sardinella* fishing, yielding at present about 50 per cent of the total *Sardinella* landings in Ghana. The catch by canoes is strongly influenced by coastal upwelling and so varies according to its intensity and duration. By contrast, landings by purse seiners have been steadily increasing, the reasons being:

1. Increased accessibility of *Sardinella* schools due to higher efficiency of purse seiners
2. Greater fishing range of motorized vessels
3. Possibility of detecting sub-surface *Sardinella* schools by acoustic fish finders
4. More reliance on other pelagic species (85 per cent of the canoe catches consist of sardinellas, this is 50 per cent of the catches of purse seiners). It is certain that in a few years the motor fishing fleet catch will completely predominate.

A negligible percentage of foreign activity is involved in *sardinella* fishing—it is predominantly Ghanaian.

The coastal upwelling off Ghana barely extends to the coasts of Togo and Dahomey. Therefore the *Sardinella* season, if any, is short, with catches poor and variable.

The shelf area from Nigeria to Cameroon and North Gabon as far south as Cape Lopez is outside any upwelling influence. Consequently there is no surface schooling and most probably no appreciable *Sardinella aurita* stocks. Canoe fishing for bonga is the main fishing activity along the coast off Nigeria as far south as Cameroon. *Sardinella eba* is found east of the Niger Delta (syn. *S. cameronensis*) and fishing for this species is fairly good.

The area south of Cape Lopez in Mid-Gabon, to Congo and Angola is under strong influence of the southern upwelling caused by the Benguella current. Here again the *Sardinella* schools appear in surface layers during the upwelling season. Indigenous canoe fishing is still predominant, but recently-introduced purse seiners compete successfully.

South from Middle Angola the permanent south African upwelling enriches the coastal waters which abound with clupeid and demersal fish. The *Sardinella*

schools, which gradually become less dense and less numerous, are overshadowed by rich stocks of *Sardinops ocellata*. Well developed purse seining yields incomparably higher amounts of fish than the *Sardinella* fishing in the northern areas.

Fishing gear and methods

Along the entire coast of West Africa a fleet ranging from dugout canoes to fully mechanized purse seiners is fishing with encircling gillnets and purse seines on the pelagic stocks of sardinellas, mackerels and carangids.

In most of the fishing nations it is possible to distinguish sharply between the indigenous fishery with canoes, sometimes with outboard motors, small undecked vessels, and the fleet of well-equipped purse seiners under command of non-African officers. This can be observed in Senegal, Ivory Coast and Congo-Brazzaville.

In Ghana, however, the dugout canoes as well as the purse seiners are entirely operated by Ghanaian fishermen. Table 2 gives the figures for the different countries. The development of the *Sardinella* fishery in Ghana and the methods employed can be considered as a blueprint for expected development in the other West African countries.

TABLE 2. COMPOSITION OF FISHING FLEETS

Vessels engaged in clupeid fisheries in 1969

Country	*Canoes*	*Purse Seiners*		*Distant Water Trawlers*
		African	*Non-African*	
Senegal	[1]	—	5	—
Sierra Leone	250	0	1	0
Ivory Coast	several hundreds	3	34 [2]	0
Ghana	1500	110 [3]	1	18
Congo (Brazz)	few	0	2 [2]	0

[1] Data not yet available. [2] Mean length: 22 m; equipped with echo sounders. [3] Mean length: 13.5 m; no acoustic equipment.

Trawling with bottom and pelagic gear for sardinellas and other pelagic and semi-pelagic species is at present restricted to the area north of 12° N. A large fleet from various nations operates here. Sardinellas, however, form only a part of the catch. Investigations over the West African area have resulted in the detection of bottom concentrations of clupeids in other areas as well, but for large long range vessels the northern area seems to be most profitable. Recently a Ghanaian commercial fishing firm exploited the pelagic stocks off Ghana with a fishing fleet consisting of a mothership, ten purse seiners and several sterntrawlers with midwater trawls. The results were not too encouraging and the fleet returned to the north.

Purse seining

A review of the Ghanaian fishing fleet for pelagic fish gives a representative picture of the fisheries along the African coast.

The simplest fishery is carried out by dug-out or open-planked canoes operating from the beach. The gear consists of an encircling gillnet called Ali net. The size is approximately 20 m deep and 200 to 300 m long. During season (upwelling period with low surface temperatures) the vessels are paddled to the fishing grounds, where schools are spotted visually, encircled with the net and gilled. Operations are mainly carried out during the night and early morning.

The first improvement is motorization; mostly outboard motors, which increases range and searching power. In Ghana nearly the whole sardinellas fleet have motors. Similar projects have started in Togo, Gambia and Senegal.

Most indigenous fisheries along the coast are of this type.

The next step in development is the improvement of the gear from encircling gillnets to purse seines. Netting with smaller mesh sizes replaces the former type, since gilling must be avoided. In Ghana this "canoe purse seine" (fig 3) introduced a few years ago, is rapidly becoming popular, as it is considerably more efficient than a simple encircling net. Pursing as well as hauling are done manually by the canoe's crew of about ten.

A vital limiting factor in all local fisheries is the poor catching ability of the nets. With limited capital available and the desire to obtain as long a net as possible, the net has a very low hanging rate. It is not generally understood that this reduces very much the depth of the net and its efficiency.

Since about 1964 a fleet of locally-built wooden purse seiners (fig 4) is competing successfully with the canoe fleet. At present, more than 100 of these vessels (between 45 and 60 ft) are operating. During 1969 the total catch

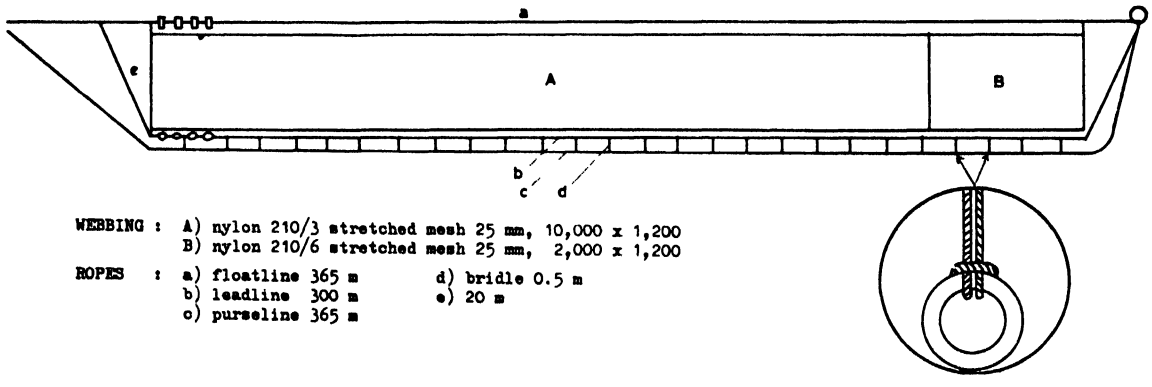


Fig 3. Canoe purse seine from Ghana

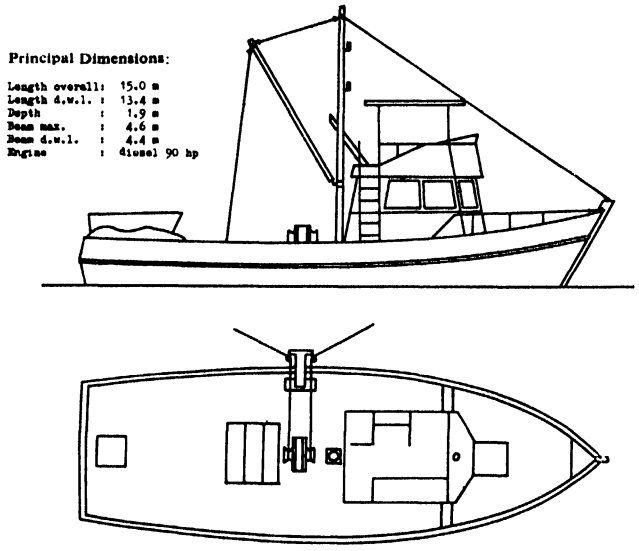


Fig 4. Plan of 15 m Ghana purse seiner

of the fleet of about 2,000 canoes (only half were regularly operating) was about 14,000 t of sardinellas, while about 100 purse seiners caught 20,000 t of pelagic fish (about 50 per cent sardinellas). More than 80 per cent of these catches were made during the main upwelling season—July till October.

These purse seiners employ basically the same fishing methods as the canoe fleet, but the range of operation is much larger. The vessels are equipped with a powered winch (mostly hydraulic) but not with a power block. The purse seine (fig 5) average size is 50 × 450 m, and is hauled in by the 23-man crew. In Ghana, as in the other countries, unemployment is a problem and sufficient manpower is available. Fishhold is not refrigerated. Often ice is taken aboard for the trips, which seldom lasts more than one day.

Only 5 per cent of the fleet is at present equipped with good working echo sounders. Fish detection still depends mainly on visual spotting so that about one-quarter of the vessels return empty.

Acoustic research shows that only a small part of available schools is visible at the surface. Also during the beginning and the end of the season, when surface schooling occurs less and surface temperature is increasing, many midwater schools are still present.

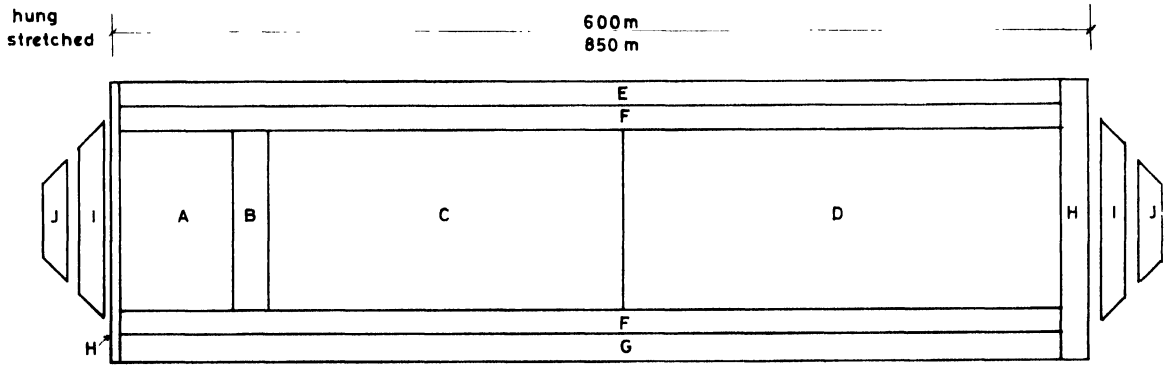
The advantages of echo sounders are now recognized and a rapid increase is expected in future. In purse seining with light attraction echo sounders are also indispensable.

The UNDP/FAO assisted Fishery Research Unit in Tema, Ghana, has designed an improved type of purse seiner/trawler, to be built locally for this fishery. Forty of these boats, equipped with echo sounders, will be built with a loan from the World Development Bank. Orders have been received also from Nigeria and the Ivory Coast.

Small fleets of purse seiners owned and commanded by non-Africans operate from Dakar (5) Abidjan (34) and Pointe-Noire (2). They are about 22 m long, are well-equipped with acoustic instruments and mostly have a power block.

Several motherships with a fleet of purse seiners operate off Senegal and Mauritania. In the near future more expeditions will arrive.

A Ghanaian owned commercial unit operates about ten steel purse seiners with echo sounders and power blocks and a mothership and carriers. The crews are Ghanaian. Several attempts have been made on the fish stock off Ghana but the fleet has moved to Gambia,



WEBBING:

A) nylon 210/18 stretched mesh 25 mm, 2,600 x 2,700
B) nylon 210/18 stretched mesh 25 mm, 960 x 2,700
C) nylon 210/15 stretched mesh 25 mm, 13,400 x 2,700
D) nylon 210/12 stretched mesh 31 mm, 1,620 x 2,100
E) nylon 210/24 stretched mesh 31 mm, 26,450 x 20
F) nylon 210/36 stretched mesh 31 mm, 26,450 x 24
G) nylon 210/72 stretched mesh 50 mm, 16,535 x 24
H) nylon 210/96 stretched mesh 30 mm, 2,260 x 24
I) nylon 210/96 stretched mesh 76 mm, 600 x 24
J) nylon 210/96 stretched mesh 76 mm, 400 x 24

ROPES:

Floatline 600 m
Leadline 600 m
Purseline 825 m

Fig 5. Ghana purse seine for 15 m vessel

where mainly sardinellas are caught and the frozen catch is transhipped to Ghana.

To overcome and extend the seasonal character of *Sardinella* fishing, the technique of concentrating dispersed schools with artificial light could become valuable. At present the use of artificial lights in West Africa is in its first stage. The first successful experimental purse seining with lights was carried out during 1963 by FAO technical assistance in Ghana. This is fully described in papers FAO/UN 1965; Zei 1966, 1970. Similar exploratory light fishing tests were done by USSR vessels during 1964. During recent years, Japanese tuna vessels in Gulf of Guinea fish for live bait using light attraction.

In Ghana, several purse seiners are now equipped with lights to attract sardinella outside the season. In Senegalese waters the use of lights in purse seining is gradually being adopted.

When a few underwater lights are submerged a few fathoms the first attracted fish appear within 15 minutes If after half an hour no fish is attracted, it is unlikely to be successful.

Figure 6 shows the echograms of a light attraction experiment off Takoradi in March, 1969. The heavy concentration of attracted fish which started appearing a few minutes after the lights were switched on, stayed in the cooler water under the well-formed thermocline.

This experience in the Gulf of Guinea shows that these techniques will become very valuable.

Trawling

Trawling for sardinellas and other pelagic and semi-pelagic species has greatly increased in the last decade.

The USSR sardinella campaign in the late 1950s, on the shelf of the Gulf of Guinea, reported rather large catches on the trawlable grounds near and on the slope of the shelf in 60 to 150 m. Similar results were obtained during the Guinean Trawling Survey in 1966/67. Both expeditions used traditional bottom trawl in the cool water below a well-formed thermocline—off Dakar and Takoradi (Ghana) were the most productive areas.

At present, a fleet of more than 200 vessels (side and sterntrawlers) ranging in size from 120 to 300 ft, from more than 12 countries (Ghana, Cuba, German Democratic Republic, France, Greece, Israel, Italy, Japan, Norway, Poland, Portugal and USSR) fishes in the area north of 12° N. The other areas are at present not exploited by long distance trawlers because of the hazardous bottom in many places.

Most of the vessels use conventional bottom trawls or high opening bottom trawls and fish between 60 and 200 m, mainly during day time. Catches are very good and consist of sardinellas, mackerels, carangids and breams.

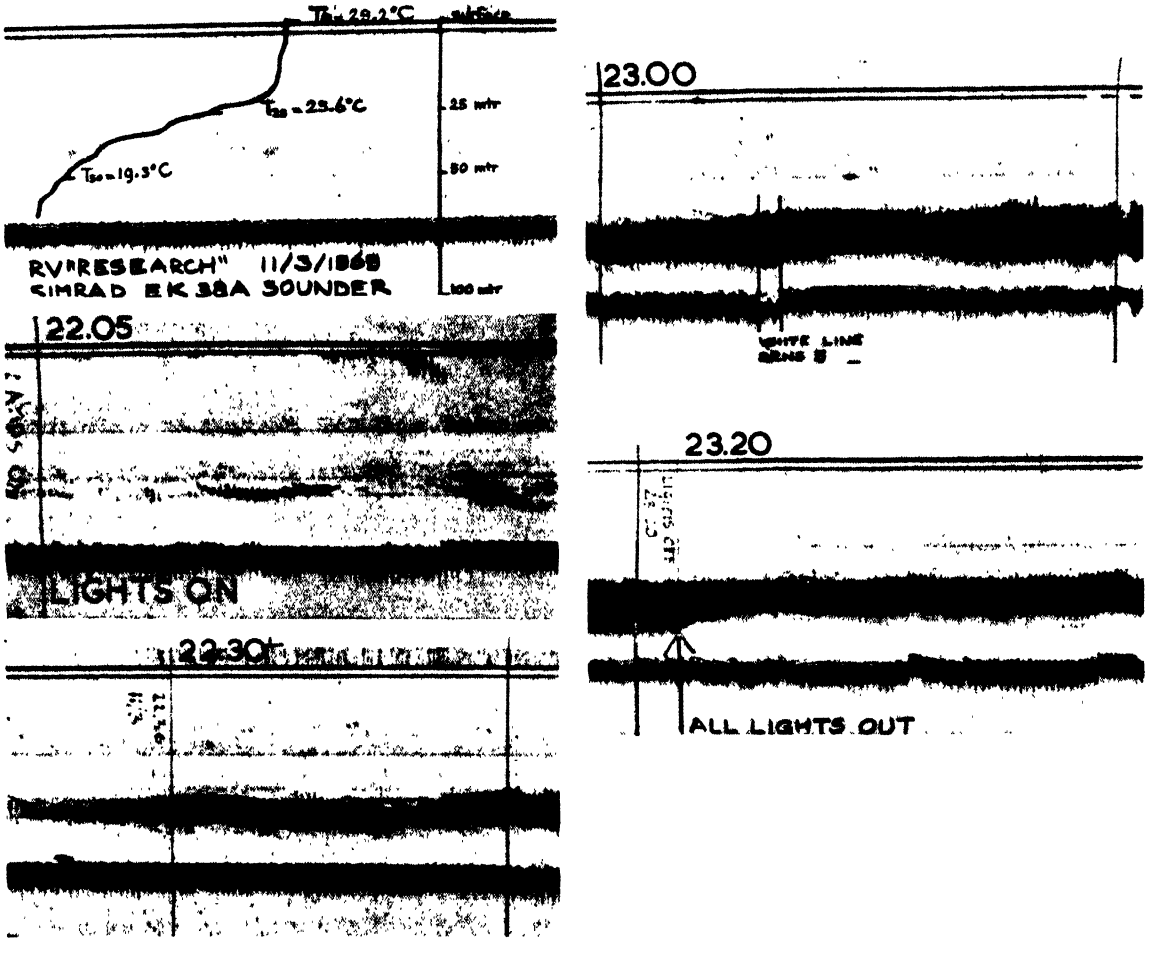


Fig 6. Echograms of a light attraction experiment off Takoradi. Lights 5 m submerged, total power 2000W

A very promising technique in this area is midwater trawling done both during day and night time, best during the night. The same species as taken by bottom trawls are caught. More and more trawlers are changing to this fishing method.

Three Ghanaian fishing companies (two private and one state owned) operate twenty large sterntrawlers. Although the stocks off Ghana have been fished by these ships repeatedly the area around Dakar is more profitable despite longer sailing time. About half the fleet uses midwater trawls. Sonar is used to search for pelagic concentrations. The catch from this fleet is landed in Ghana for local consumption. The other part of the catches, made off Senegal and Mauritania, which is far larger, is shipped to home countries of the vessels.

FUTURE DEVELOPMENT

In view of the great demand for fish in the countries from Senegal to Congo, with about 100 million inhabitants, and of the apparent abundance of pelagic fish resources (at present insufficiently utilized), fishing for sardinellas should be given top priority. One might roughly estimate the future landings of sardinellas in this region to increase to several times the present catch. The United Nations Development Programme has been rendering assistance in national fishery development schemes from Senegal to Congo with particular emphasis on the survey and exploitation of stocks of sardinellas. Five fishery research projects have been launched with a realistic hope that in a few years they will throw more light on the biology of sardinellas and secure more efficient fishing with new techniques, gears and boats.

In that future development the following course might be expected: In the local short range fisheries, the existing canoe fleet will be modernized by intensified use of outboard motors and small echosounders; the "canoe purse seine" now in use in Ghana will be adopted everywhere. Further construction of more and better harbours will increase numbers of modern purse seiners and replace the existing canoe fleet in part.

Purse seining with light attraction, mainly from motor vessels, but also from canoes, is expected throughout the entire Gulf of Guinea to increase the catch by extending the fishing season.

A rapid increase in use of echo sounders is expected, and with light attraction and acoustic fish finders will expand the fishery to a year-round operation.

The distant water fisheries, concentrated in the area off Senegal and Mauritania, are expected to continue expanding with the emphasis on the use of midwater trawls.

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More recent information on sardinella fisheries in general, particularly on catch statistics, has been obtained by helpful collaboration of the UN/SF/FAO fishery projects in the West Africa Region.

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The American Tuna Purse Seine Fishery

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La pêche américaine du thon à la seine coulissante

La pêche américaine du thon à la seine coulissante a lieu sur l'albacore (*Thunnus albacares*), le listao (*Katsuwonus pelamis*), le thon rouge (*Thunnus thynnus*) et le germon (*Thunnus alalunga*). Cette pêche, qui débuta peu après 1900, s'est développée dans trois directions: pêche à l'appât vivant pour l'ensemble des quatre espèces; pêche à la seine coulissante pour le thon rouge, le listao et l'albacore; pêche aux lignes traînantes pour le germon. La pêche à l'appât vivant a été la plus importante jusque vers 1960. Par suite de la contrainte économique et des progrès technologiques qui ont amélioré l'efficacité de la seine coulissante, presque tous les thoniers clippers à l'appât vivant ont été transformés en seineurs durant la période 1957–61. La période 1961–70 a été caractérisée par le développement et la modernisation de la flottille des seineurs. Actuellement, plus de la moitié du tonnage et environ un tiers de cette flottille sont constitués par de grands navires récents, construits pendant cette période. Avec l'avènement d'une réglementation par quota concernant l'albacore dans le Pacifique tropical oriental et la durée de plus en plus courte chaque année des saisons ouvertes à la pêche, les grands seineurs ont commencé à étendre leurs opérations dans des secteurs en dehors des lieux de pêche américains traditionnels du Pacifique oriental. Ces bateaux sont de plus en plus nombreux à se déplacer vers l'ouest, à l'extérieur de la zone réglementée, et vers l'est, en Atlantique, jusqu'à la côte d'Afrique. La production du thon a commencé à diminuer en Californie méridionale, car la plupart des nouveaux seineurs ont choisi Puerto Rico comme port d'attache. On s'attend à l'avenir à voir un accroissement de la demande et des prix du thon avec des captures en augmentation, une exploitation de nouveaux secteurs et des rendements de pêche en diminution. Si les Etats-Unis veulent rester compétitifs, de nouveaux progrés devront intervenir dans la echnologie de la pêche du thon à la seine.

La pesquería norteamericana del atún con redes de cerco de jareta

La pesquería norteamericana del atún con redes de cerco de jareta se dedica al rabil (*Thunnus albacares*), barrilete (*Katsuwonus pelamis*), atún de aleta azul (*Thunnus thynnus*) y albacora (*Thunnus alalunga*). La pequería del atún comenzó poco después de 1900 y se desarrolló en tres direcciones: pesca con cebo vivo de las cuatro especies; pesca con artes de cerco de jareta del atún de aleta azul, el barrileta y el rabil; y pesca con curricán de la albacora. Hasta 1960 la más importante fue la pesca con cebo vivo. A causa de la presión económica y de los progresos tecnológicos que incrementaron la eficacia de la pesca con artes de cerco, casi todos los clíperes destinados a la pesca del atún con cebo vivo se transformaron en cerqueros en el período 1957–61. El período 1961–70 se caracterizó por el aumento y modernización de la flota de cerqueros. En la actualidad, más de la mitad del tonelaje y cerca de un tercio de la flota de barcos cerqueros está constituído por embarcaciones grandes y nuevas, construídas durante dicho período. Con la implantación de un sistema de cupos para la pesca del rabil en el Pacífico oriental tropical y con la consiguiente reducción progresiva de la temporada anual de pesca, los grandes cerqueros han empezado a extender sus operaciones a zonas situadas fuera de los caladeros americanos tradicionales del Pacífico oriental. Son cada día más las embarcaciones que se dirigen hacia el oeste, saliendo de la zona regulada, y hacia el este, penetrando en el Atlántico en dirección de la costa africana. La producción de atún ha empezado a desplazarse del sur de California, porque la mayor de los nuevos cerqueros han escogido Puerto Rico como puerto base. En el futuro, es de esperar un aumento de la demanda y de los precios del atún, a la par que un aumento de las capturas y la explotación de nuevas zonas, con una disminución de los indices de captura. Si los Estados Unidos quieren mantener una posición competitiva, será preciso que se introdurcan nuevos adelantos en la tecnología de la pesca del atún con artes de cerco de jareta.

THE American tuna fishery depends mainly on four species: yellowfin (*Thunnus albacares*) and skipjack (*Katsuwonus pelamis*) found mostly in the tropics and constituting the bulk of American tuna landings; and bluefin (*Thunnus thynnus*) and albacore (*Thunnus alalunga*) in temperate regions. In 1960 to 1968, the annual U.S. tuna catch was about 145,000 to 193,000 t (Lyles, 1969). Principal fishing methods are purse seining, pole and line fishing with live bait and trolling.

The present American tuna purse seine fleet stands out as one of the most modern and efficient in the world. The purse seiners are among the largest, most complex and costly of fishing vessels. The growth of this fishery in a country where fishing has, for many years, declined in relative national and world importance seems almost a paradox. The fishery is marked by alternate crises and massive responses to them.

Knowledge of the origins of tuna purse seining is basic to understanding currently used gear methods. Purse seining for tuna began out of San Pedro, California, about 1914. The first purse seines used were designed primarily for "whitefish" (barracuda, white seabass and yellowtail). A typical "whitefish" net was 200 fm long and 18 fm deep. The stretched mesh size was 2½ in., constructed of No. 12 (827 Tex) cotton twine. The netting was hung tightly to the floatline with hanging coefficients (k_h) of 0.91–1.0 (hanging coefficient (k_h): ratio of length of line to adjacent stretched length of webbing (Ben Yami, 1959)). The rope leadline was 10 to 15 per cent shorter than the floatline. The wing ends terminated at vertical breastlines which were usually about half of the net's depth. This net was adapted from the salmon purse seine design used in the Pacific Northwest. Aside from material and size, these early "whitefish" nets are remarkably similar in basic design to tuna purse seines in use today. Typical purse seiners then were about 50 ft long with 12 ft beam.

The first purse seine designed specifically for tuna was built about 1916 by Van Camp Sea Food Company. This net was 420 fm long by about 35 fm deep. The stretched mesh size was 11.4 cm constructed mainly of No. 36 cotton. A surplus navy tow boat, 33.4 m long was converted to a purse seiner to handle this net. This first experiment with a "big boat" and "big net" was doomed to an early failure. The bulky net proved too unwieldy to manage. In less than a year this experiment ended and two smaller purse seines were made from this net and fished from the *A.M.Z.* and *California*, both purse seiners of about 15.2 m length.

During the first summer with this cut-down tuna purse seine, the *A.M.Z.*, under Captain Anton Zankich, set on a large school of bluefin. All but 10 to 15 t was lost because of handling difficulties. This gave rise to optimism that net handling methods could be improved so that tuna schools much larger than five or six t could be taken for canning. Commencement of bluefin canning about 1918 was probably the salvation of the industry. The increased market attracted more salmon seiners from the State of

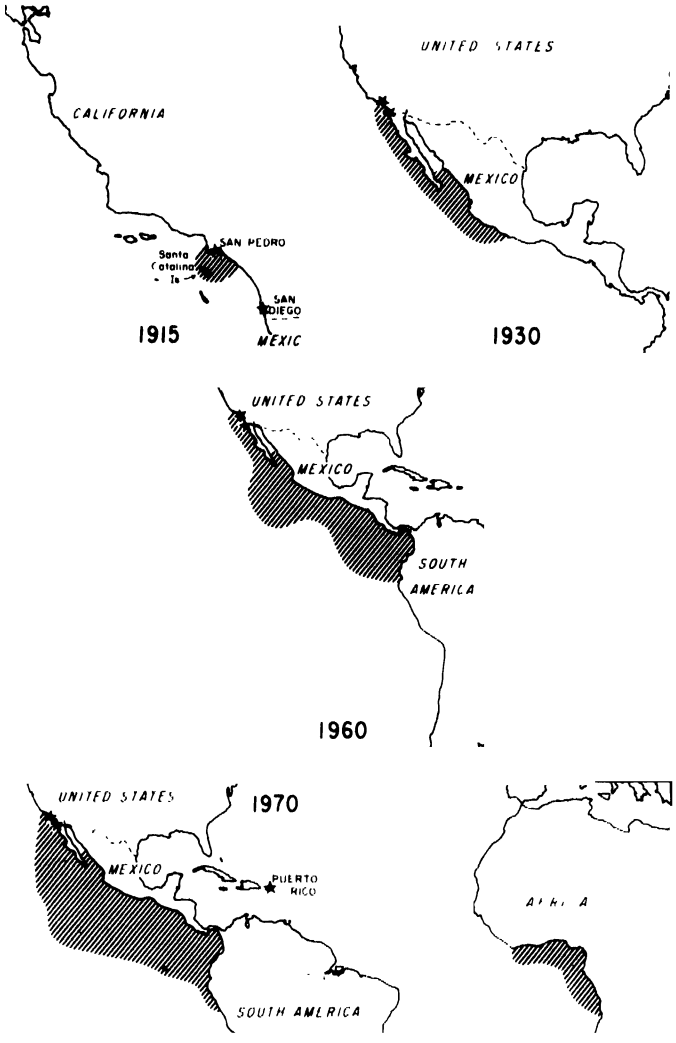

*Fig 1. Expansion of U.S. tuna fishing areas, 1915–1969. * = tuna purse seining ports*

Washington until a peak of about 125 purse seiners was attained in the San Pedro bluefin fleet. Because of technological difficulties, however, the success of this large fleet was poor and by 1920 most of them had returned to their original ports.

In 1923 the *Diamond*, under Pete De Maria, was the first tuna purse seiner to fish Mexican waters as far south as Cape San Lucas (*Diamond* also had the first diesel main engine in the fleet, a 100 hp Fairbanks Morse). By 1929, led by the *Sea Rider*, built by Captain Peter Dragich, Sr., purse seiners as large as 100 t capacity were being built specifically for operating off Baja California and had begun to take tuna from the Gulf of California.

Power brailing and the boom and winch to haul the net had been developed by this time. The net was strapped and pulled in, a section at a time, with the winch and block from the main boom. The same type of gear was also being used to mechanize the "drying up" operation. A technique for "cutting" the net to divide large catches into more manageable portions was also developed.

With the development of mechanized methods of net handling, the purse seines were made larger—up to 300 fm

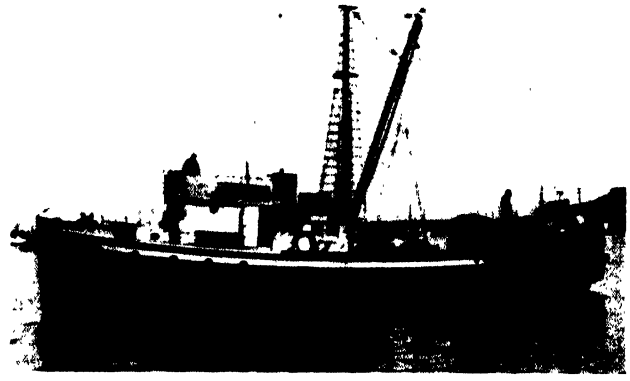

Fig 2. Tuna purse seiner Oakland. *82 ft long with 21½ ft beam. Photo by R. S. Croaker, Calif. Dept. of Fish and Game, Jan. 1931*

long by 28 fm deep—and of heavier construction. Through more trial-and-error experimentation, optimum mesh size stabilized at 10.8 to 11.4 cm stretched mesh. The main drawback of these nets was still the cotton material. Rapid deterioration started from first use and netting two years old, if it lasted that long, was worthless. Nets were constantly being repaired. Whenever there were spare moments, men were replacing panels, shifting rotten netting to areas of lesser strain and sewing holes and rips in badly decayed cotton.

The use of ammonia refrigeration, in conjunction with crushed ice, began in 1930, when purse seiners *Musketeer* and *White Star* installed refrigeration coils in the fish holds to extend the usefulness of ice. The use of refrigerated brine followed in 1932—preceded by its successful use on a bait-boat. At first the brine was circulated through a cooler and then through the fish wells which did not contain cooling coils. Slowly, vessels of the purse seine fleet began to add, or were built with, refrigeration machinery and by 1945 all these seiners were so equipped.

The purse seiner fleet generally operated locally from the Channel Islands off San Pedro south to the waters along both sides of Baja California. Some of the larger vessels, however, did venture farther south. In 1932, Captain Nick Dragich took the *Sea Tern* (previously named the *Musketeer*), a 32 m purse seiner of 136 t capacity, to the Galapagos Islands. Dragich was also the first to set on porpoise schools for the tuna found with them. A purse seiner of this time period is shown in fig 2. After the late 1930's, the normal maximum run for San Pedro tuna purse seiners was to between Manzanillo and Acapulco, Mexico.

Starting in the period 1925-28, purse seines were adopted for sardine fishing at San Pedro and began to replace the lampara nets previously used. For the next 20–30 years, until the decline in abundance of the California sardine and mackerel resources, purse seining for tuna was of secondary importance for many of these smaller purse seiners. They fished for tunas when they appeared during the off-season for sardines (Shimada and Schaefer, 1956).

With improved refrigeration making longer trips possible, further increased vessel size appeared to be logical. In 1937, the first steel hulled purse seiner,

Paramount, was built. This vessel was 37½ m long with a capacity of 309 t. It carried a net 420 fm long by 42 fm deep. In 1947, the *Santa Helena*, capable of loading 328 t of tuna, was built. Her net was 500 fm long by 45 fm deep—but still of cotton. The practice of tarring nets to help extend their life had long been practised by this time, but the tar added significantly to weight. With the corks then used, the *Santa Helena's* giant net would not stay afloat during pursing, but the problem was solved by lashing about twenty oil drums along the corkline.

The trend to larger purse seiners culminated in the *Falcon*, a converted 53.5 m Navy tow boat capable of carrying about 600 t of tuna. She had the shortest career of the fishing fleet. Her maiden voyage lengthened into weeks, then months as her weary crew bent to the discouraging task of filling her insatiable holds. Finally, she returned to port with about a half load and retired from fishing.

It was found that some of these larger purse seiners could operate more profitably as bait-boats, and several were converted. Paralleling the early growth of the tuna purse seine fishery, the bait-boat fleet at San Diego developed in size and numbers and began to extend operations as far as Peru. Thus, while one segment of the U.S. tuna fleet developed an efficient purse seine technology, but remained largely on local fishing grounds, the other segment, with their large and modern tuna clippers, developed familiarity with distant grounds. By the late 1950's, all the ingredients for a successful high seas tuna purse seiner fleet were present in these two fleets. The catalyst that brought them together was a growing economic crisis for American tuna fishermen.

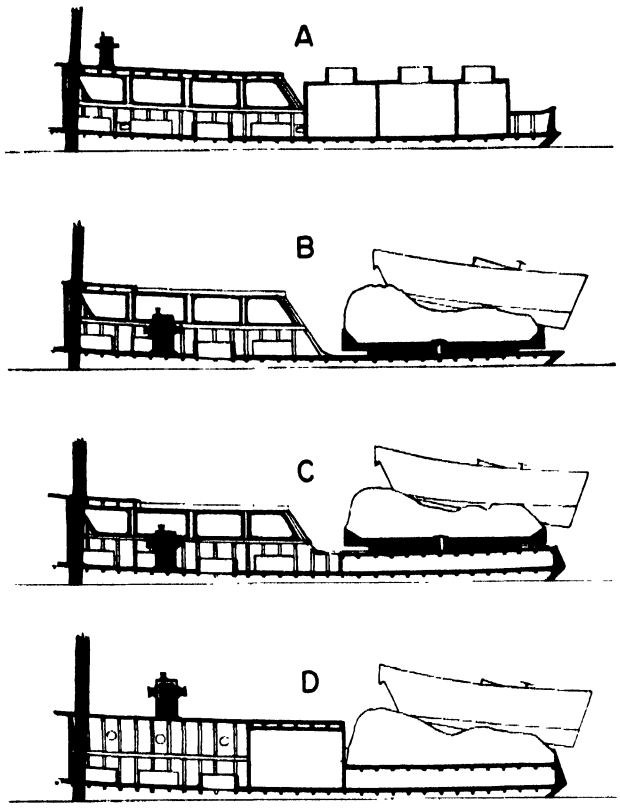

Fig 3. Stern cross sections showing: A, typical tuna clipper; B, turntable, net and skiff on early conversion; C, watertight void space under turntable improves vessel safety; D, enclosed lower deck, raised net platform, and deck-mounted fish well increases fish-carrying capacity. (After McNeely, 1961)

THE TRANSITION PERIOD

Purse seining in the tropics was carried out by American fishermen from 1925 on, but with limited success because of rapid deterioration of cotton netting. In the 1950's, an economic squeeze caused by low-priced imports of Japanese-caught tuna, forced American fishermen to increase their efficiency, and they concentrated on purse seining technology. This time, due to two major technological developments, nylon nets and the power block, the method became feasible for fishing with very large nets in warm waters. The first all-nylon tuna seine, however, was not an American innovation as popularly thought (and as stated by McNeely, 1961), but was fished by a Peruvian boat in 1954 (Anon, 1959). The first American use of an all-nylon seine for tuna was in 1956 by the *Anthony M.* (Anon., 1956.)

The now well-known advantages of synthetic fibre nets in giving superior strength and larger catches were followed by the puretic power block. This was introduced to tuna seining by *Anthony M* in 1955. The largest contribution of the power block was in time saved in retrieving the net after an unsuccessful set. The time was reduced by nearly half (Orange and Broadhead, 1959), thus allowing many more sets of a large net to be made in one day.

Spurred by the success of the *Anthony M* with the new gear, the Peru-based American clipper *Sun King* in 1957 was converted to purse seining, and the first American-based clipper to be converted, the *Southern Pacific*, became a seiner soon after. A chain reaction followed, and by 1961 about 75 vessels were converted or undergoing conversion.

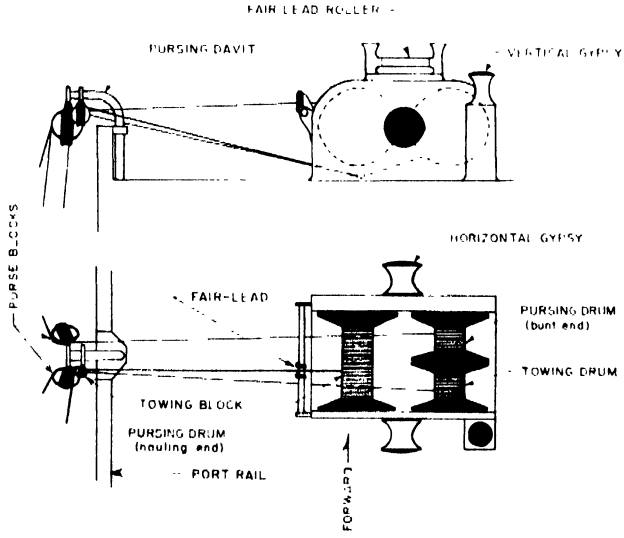

Fig 4. Purse seine winch drum and cable arrangement (After McNeely, 1961)

Table 1 shows that in 1961 the number of seiners in the long-range fleet was more than twice that in 1958. Today, there are very few bait-boats left (43 out of a fleet of 163 vessels), and the tuna fishery is effectively a purse seine fishery.

TABLE 1. LONG-RANGE CALIFORNIA AND PUERTO RICO BASED VESSELS ENGAGED IN THE EASTERN TROPICAL PACIFIC TUNA FISHERY DURING THE YEARS 1950–1969

Year	*Baitboats*	*Purse seiners*	*Total*
1950	204	67	271
1955	172	63	235
1959	140	53	193
1960	70	83	160
1961	44	114	158*
1962	36	103	139
1965	44	111	155
1968	50	104	154
1069	43	114	157

* Does not include about 22 other (mostly under United States flag) based in Costa Rica, Mexico and Peru.
Source: Inter-American Tropical Tuna Commission, as reported in McNeely (1961) and Annual Reports of the Inter-American Tropical Tuna Commission for 1967 and 1969.

Cost of earlier conversions varied between US$50,000 and US$100,000 depending on design and quality of materials and workmanship. Added was the cost of a nylon purse seine averaging about US$50,000.

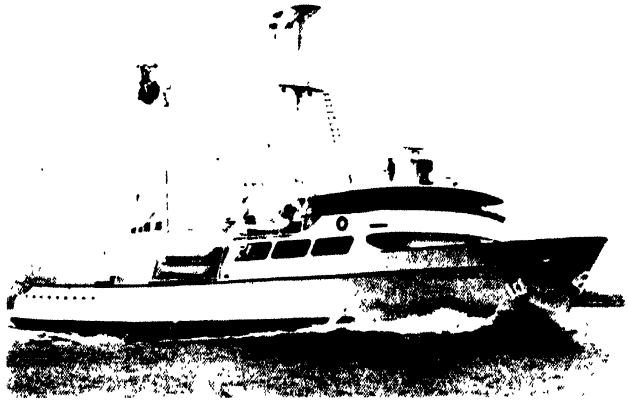

Fig 5. Vivian Anne *entered the fishery in 1969. Length 144 ft, capacity 465 tons. Photo courtesy of Arthur DeFever, Naval Architect*

Details of conversion

The earliest conversions from clipper to seiner involved little more than clearing away the gear and structures required for bait fishing and installing those for seining. The bait tanks, piping, circulation pumps, fishing racks and accessory gear were removed, leaving a clear afterdeck for the seine-fishing gear. Amidship upper decks were partially cut away on the port side aft.

An auxiliary speedboat and accessory gear were stored on remaining upper deck space aft, and guard rails were installed around exposed sections of upper decks. No hull modifications were required.

It was necessary to install masts and booms to withstand the stresses of net hauling, "drying up" and lifting aboard the heavy seine skiff. These were constructed of double strength tubular steel with multiple diameters fitted one inside the other and welded at external joints.

Fig 6. Cabrillo *entered the fishery in 1968. Photo courtesy of J. M. Martinac Shipbuilding Corp.*

Seining operations also require a heavy-duty winch. The winch used in early conversions had a minimum of three drums, two gypsies and two heavy-duty lashing bits (fig 4, from McNeely, 1961). The following description of the winch is repeated verbatim from McNeely (1961):

> "Drums—Three drums are mounted on two parallel drivershafts running fore and aft in the winch housing (fig 4). The single purseline drum located on the port driveshaft holds about 600 fm of wire rope purseline made of two end sections measuring 160 fm and 330 fm long . . . $\frac{5}{8}$ in (1.6 cm) diameter galvanized steel and a 110 fm centre section made of $\frac{3}{4}$ in (1.9 cm) stainless steel wire rope. Two drums, located on the starboard driveshaft, have independent drives and controls. The forward

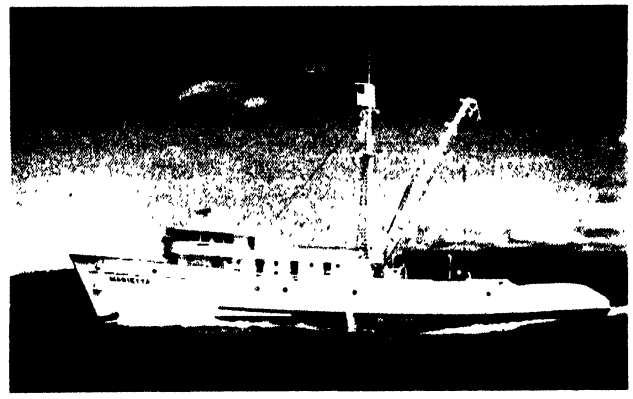

Fig 7. Marietta *entered the fishery in 1968. Photo courtesy of J. M. Martinac Shipbuilding Corp.*

drum in the double drum section is used to haul in the bunt-end purseline, while the after drum is used to hold approximately 200 fm of $\frac{5}{8}$ in (1.6 cm) galvanized steel wire rope towing cable. Roller fairleads on the base or on top of the winch guide cables from the starboard drums past the port drum and through a purse block and towing block mounted on the purse davit by the port rail. Level-wind fairleads are driven manually or by hydraulic or air motors and usually are installed on the port drum only. Clutches and brake shoes on the pursing drums and towing drum are operated manually or by hydraulic or air cylinders. One newly designed winch has small control levers, mounted in a control console . . . to allow operation of all drums simultaneously by one winch operator.

"Cargo drum—A fourth drum (cargo drum) of small diameter is sometimes located above and between the two large drum sections. It is used principally for operation of a "choker" rope during "sacking-up" operations. Fairlead blocks on the starboard rail lead the choker rope along the starboard rail aft and then to the port rail where strapping and choking operations are performed.

Fig 8. Hull 79 under construction. Length 200 ft, capacity 1,335 tons. Photo courtesy of Campbell Machine, Inc.

"Gypsies—Two 12 in (30.4 cm) horizontal gypsies, and sometimes an additional 10 in (25.4 cm) vertical gypsy, are mounted on the winch for general utility hauling. The forward horizontal gypsy is used more frequently than the other two and has sea water piped to it for cooling purposes during long periods of holding . . . Nylon, manila and wire ropes are commonly hauled on the seine-winch gypsies. When hauling of wire rope is anticipated, surfaces of gypsies are hardened.

"Power supply—A variety of power supplies are utilized to operate seine winches. One of the more common drives is the electric motor which, due to the small space available in the shaft alley beneath the winch, is applicable as well as economical. Some vessels employ hydraulic motors or diesel engine drives coupled through line shafting or mounted directly beneath the winch. The vulnerability of electric motors and controls to damage from salt water, and the advantage of controllable speed and torque in hydraulic drives, makes installation of the latter power source desirable."

Use of a power block required a hydraulic drive, and complete hydraulic drive systems for boom-topping winches, vanging winches and the pursing winch were soon adopted by the fleet.

Special fore-deck installations are required for operation of a purse seine, including rail cleats, rope fairlead sheaves and cork purseline winches. The corkline is pursed by passing lines through a port rail sheave to the corkline winch or to the anchor winch gypsy.

A special heavy-duty davit at the port rail in line with the pursing winch supports the purse blocks and the towing block. The davit is constructed by bending a heavy steel pipe to form a right angle elbow and welding a steel plate stiffener across the angle for support. Heavy duty purse blocks are mounted fore and aft on hanger eyes constructed of heavy steel plate and welded to the pipe on the outboard end, and a smaller towing block is attached to a third eye on the upper side of the davit.

The turntables, which were included in the early conversions, were about 7.6 m square and constructed of heavy timbers. Support was provided by heavy-duty steel roller pedestals secured to the deck, and the table rotated on a circular steel track attached to its underside.

Fish hoppers to receive brailed fish were constructed in a variety of shapes and materials. The hopper was positioned and pivoted in a socket installed on the deck. A chute from the hopper to the wells was constructed in sections, of sheet metal and Y-shaped pedestals supported it along the deck.

The seine skiff

The size of the seine skiff is directly related to the size of the net and the size of the seiner. The skiffs used initially were about 6.1 m long, 4.6 m wide and 1.2 m deep and constructed of plywood sheathed with fibreglass. To allow the skiff to pass freely over the corkline, tapered skegs are attached parallel to a tapered keel, and the propeller is caged. A heavy steel plate on the bow, with eye attached, provides great strength for hoisting or towing. A towing bit made of steel pipe is mounted amidships, securely fastened to the keel, and braced.

Propulsion is provided by a diesel engine, power varying greatly with size of the skiff and individual preference. Engines in early skiffs were between 75 and 150 hp. Considerable power is required during the towing operation, when the skiff tows the seiner on 91 m of 1.9 cm nylon line and keeps it from being pulled over the net during pursing and hauling. A 15.4 cm vertical gypsy is driven off the engine and used for pursing corks and manoeuvring the brail during transfer of fish from another vessel.

A rubber hose of 25.4 cm is fitted over the skiff rail to provide a friction surface for webbing that is pulled over it during sacking-up and also to act as a fender and to provide footing.

Later conversions

Later conversions incorporated features to increase safety and fish capacity. Watertight spaces were built under the turntable (C, in fig 3) to increase buoyancy in bad weather.

In still later conversions, the turntable was eliminated and a raised net platform substituted (D, in fig 3) combined with a completely enclosed watertight lower deck, increasing both safety and capacity. Extra fish wells were sometimes installed under the platform. The purse winch was installed on the raised deck. Fish are lifted to the raised deck and unloaded into hatches that lead to hoppers and distribution chutes between decks.

The fishing operation

Preparing the gear for a set. When a turntable is used, the net is stacked in three parallel piles running athwartships, the corks on the port side and the rings on the starboard. To start the stacking operation, a line is passed over the power block and snapped to the "triangle" end bracket of the hauling end of the net, which is then pulled through the block. The triangle is hung over the stern of the turntable, and the crew spreads out across the after end of the table to stack the net.

A line is passed through the rings as they are stacked and used later as a leader for threading the purse cable. About half the net is stacked in the first of the three piles (closest to the stern), which reaches a height of about 2.1 m. To start the second stack, the main boom is raised, bringing the power block forward. The second stack is allowed to reach a height of about 1.5 before the third is started. The third stack reaches a height of about 0.6 m. The incline yielded by the three different sized stacks is useful in bringing the seine skiff aboard atop the net (after the turntable is rotated).

The turntable is rotated to setting position with a cable from the pursing winch and secured with a pin set in a deck socket.

Next the seine skiff is lifted to its position atop the net pile with a 10 T capacity double block on the main boom. The following description of the hook-up is quoted from McNeely (1961):

> "The end of the seine towing cable is pulled from the winch towing drum, passed through the towing block, and connected to the hauling end "triangle" bracket. The purseline is then pulled from the winch, passed through the stern purse block and tied to the purse ring threading rope. The purseline is pulled through the rings . . . a sufficient distance to allow connection to an intermediate hauling cable which is coiled inside the skiff. A long link on the end of the purseline is then connected to a purseline release on the bunt end "triangle" bracket. The next step is to secure the intermediate hauling cable to a cleat near the amidships rail on the starboard side of the skiff."

On the fishing grounds, the skiff is shifted to the rear of the net pile. A steel cable painter is shackled to the bow of the skiff and secured to a pelican hook mounted on the winch. Safety is provided by a pin in the pelican hook.

Setting the net. When fish are sighted the pin is removed from the pelican hook, and when the signal to "Let her go!" is given, the hook is opened with a hammer, allowing the skiff with the net end attached to drop into the water. The skiff acts as a sea anchor and pulls the first portion of the net over the stern. Pull on the skiff is controlled by varying tension on the purseline with the pursing winch.

The set is controlled by the "fishing captain" on the mast or by an observer in an aircraft. The turning rate and speed of setting depend on behaviour of the school of fish. If the circle that can be completed with the net alone is too small, a larger circle can be made by letting out excess purseline and towing line.

When the vessel approaches the skiff at the completion of the circle, engines are reversed to bring it to a stop, and a heaving line is thrown to the skiff. The heaving line, which is secured to the forward purse block, is attached to the intermediate hauling line in the skiff, whereupon the hauling line and net end are released from the skiff, leaving it free to patrol the open water under the towing line between the vessel and the other end of the net, or, if no towing line is used, to take up its towing station at the opposite side of the vessel. The intermediate hauling line is passed through the purse block to a gypsy that is used to pull in the bunt end of the purse-line and the end of the net, which is attached to a steel hook on the davit. The purseline is then connected to the winch, and the release connecting it to the "triangle" is opened, freeing the purseline from the net end, so that pursing can begin. The bow breastline, after being disconnected from the "triangle", and the cork purseline are secured to cleats along the port rail of the bow.

Meanwhile, the towing line and purseline are being hauled by the winch. When all the towing line is in, the skiff commences its towing operation from the starboard side, attempting to keep the vessel square with the net and from being pulled into the net during pursing. When the towing line is in, the stern "triangle" is attached to a second retaining hook on the davit, towing line is disconnected and wound up on the winch.

The net is pursed until the rings are together and begin to come out of the water. Then the hoisting line, which was previously passed over the power block, is connected to the hauling end "triangle" and the end of the net is hoisted about 4.6 m in the air, away from the purse davit. A retaining line is placed around the netting to remove it from the port rail area so that the rings may be brought aboard. The following description of the handling of the rings is from McNeely (1961):

> "As the purse rings come out of the water, cable clamps, joined by a short bridle, are fastened to the purseline and hooked to a double block hoist located on the main boom. Cable is then slacked off the purse winch drums, and the purselines are removed from the purse blocks. The rings, dropper chains, and leadline are then hoisted high in the air. When these are well above the vessel rail, they are lowered slowly to the deck. The rings are then separated into four or five successive groups and tied with retaining chains which are permanently attached to the starboard rail. This prevents their being dragged back into the water.
>
> "Three snatch blocks are then employed to return the purseline, which had been wound up on the starboard winch drum, through the rings and back to the port winch drum. Two of the blocks are attached to the purse davit and one is located near the deck on the forward and starboard side of the turntable base. When this has been completed and the purse rings are free of the purseline, hauling of the net proceeds. Another method used to free the purse rings from the purseline, which results in a saving of time, is to open "figure eights" or split links, remove the line, and reconnect the ends. Twists in the purseline are also removed at this time."

Hauling the net. When the purse rings are free, hauling of the net begins. The retaining line is loosened, and the hauling end is pulled over the power block with the hoisting line. The purse rings are released in groups of two or three and, individually passed over the block, are retrieved, and threaded on a line. The purseline is inserted later as described above.

Now the net is dried up (hauled and stacked) until the area occupied by the fish is minimal. Excessive weight in one area may necessitate pursing the corkline. This operation is described in "Porpoise Fishing". If the catch is estimated to be very large (over 40 T), it may be split into two or three lots by pulling one or two "zipper lines". The skiff, its towing duties completed, comes alongside and picks up the corkline at the outboard side of the area containing the fish, forming a pocket. The fish are concentrated by further hauling of the net, and the corkline is secured fore and aft to both the vessel and skiff.

The "sack" or bunt is dried up further by strapping aboard 4.6 m sections of webbing with a winch power, using slings. When a section has been lifted, it is secured with a choker line pulled tight by the cargo hoisting drum or a gypsy on the winch, to prevent it from slipping back into the water. This operation is repeated until the fish are concentrated in a compact bag at the surface.

Brailing. The following description of the brailing operation, which follows "sacking up" is from McNeely (1961):

> "The small boom, used principally for brailing, is then vanged into the most advantageous position for handling of fish during the brailing operation.
>
> "The brail with hoisting sling attached is then lowered to the skiff men who guide the brail vertically down along the side of the skiff. The skiff men signal the winch operator to lower or hoist the brail by using a small police whistle or voice and hand signals. A 2 in (5 cm) diameter aluminum handle 16 ft (4.9 m) long on the brail allows the skiff men to guide the brail into the fish. When the brail is in position to take a full scoop of fish, the winch man is signalled, and as the brail is pulled up through the fish, the skiff men guide it to the side of the seiners until it emerges from the water full of fish.
>
> "A third man in the skiff holds tension on a brail purseline made of small chain until the brail is positioned over an unloading hopper. He then releases tension on the brail purseline, which opens the bottom of the brail bag, allowing the fish to spill into the hopper. When the brail is empty of fish, the chain man pulls on the brail purseline which closes the bottom of the brail and helps return it to the skiff men. The operation of brailing is repeated until all the fish are removed from the bag.
>
> "Fish deposited in the hopper are guided to selected brine tanks by a series of sheet metal chutes."

After brailing is completed, the strapped down webbing is released and the corkline unlashed from the vessel and skiff rails, and hauling and stacking is resumed until all the webbing is out of the water. Before the end of the net goes through the power block, the cork purseline and breastline are retied to their original attachment points, to the breastline and to the "triangle" respectively, and the hoisting line is attached to the "triangle" so that it may be passed over the power block for use during the next set.

1961–70 EXPANSION AND NEW CONSTRUCTION

On the heels of mass conversion of bait-boats to purse seiners began a decade that further revolutionized the tuna purse seine fishery. The fleet of today is dominated by newly-built, large capacity seiners, vessels from 42.4 m to over 76 m long. These seiners are moving into new areas of fishing with new fishing tactics, modern gear, and increased efficiency.

Technology

The most distinguishing characteristic of the purse seiners since 1960 is their size. Before 1961, the largest seiners (converted bait-boats) were of about 591 t carrying capacity. Only two were larger than 455 t and the average size lay somewhere between 182 and 273 tons.

Since 1961, 38 new purse seiners, including nine conversions from military hulls, have been added. The largest of these vessels is nearly 829 t and the average size is 655 t. Typical purse seines of this period are shown in figs 5 to 8. The total capacity of these seiners, at the end of 1969 (23,268 t) comprised 52 per cent of all U.S. purse seiner capacity (44,674 t, 120 vessels). Forty-three bait-boats represented an additional 3,710 t of capacity (Inter-American Tropical Tuna Commission, 1970).

Several other tuna purse seiners are (in 1970) under construction in San Diego, California and Tacoma, Washington. Among these is one of 1,820 t carrying capacity, nearly twice the size of the largest tuna purse seiner now in existence.

TABLE 2. ADDITIONS TO U.S. PURSE SEINE FLEET EXCLUSIVE OF BAITBOAT CONVERSIONS, 1961 TO 1970

Year built or year converted from military hull	*Number of vessels added*	*Added capacity as of 1969*
		t
1961	3	1705
1962	4	2415
1963	4	3425
1964–1966	3	1769
1967	2	1360
1968	7	5003
1969	13	7375
1970*	2	1592
Totals—	38	24819

* As of 13th March.
Source: Unpublished data of the Inter-American Tropical Tuna Commission.

Increasing size within reasonable limits offers a number of advantages which may help improve profitability: as vessel size increases, cost of construction per ton of capacity decreases, as do many operating costs. The ratio of fishing time to travel time increases with vessel capacity and, of course, large vessels are more seaworthy and have greater range than smaller vessels. At some point in size, depending on conditions of operation, these advantages are offset by the drawbacks of practical limits on net size, crew size, school size of tuna, length of trips, and other factors which tend to increase operating costs per ton of fish caught.

Many owners of small purse seiners are prevented from buying larger, more efficient vessels because of the lack of a market for their older boats. One fleet-owning corporation, after an analysis of optimum sizes of purse seiners (Green and Broadhead, 1965) found a way out by enlarging existing vessels. Over a period of four years, seven steel-hulled purse seiners were cut in two near amidships and sections spliced in to lengthen them by 14 ft to

32 ft (4.26 to 9.7 m) (fig 9). Carrying capacity was thus increased by 73 to 164 t. The changed length to beam ratio also improved speed by about ½ kn and sea-keeping ability. All seven of these vessels were of about 309 t capacity before the operation. They are said to be rapidly paying off, through increased efficiency, the cost of their modification.

Hull design and general arrangement of the first new purse seiners differed little from the familiar tuna clipper of the past. Since that time, new construction has been marked by occasional innovations and establishment of new trends until the seiner of today appears quite different from early conversions. Externally, several new seiners stand out sharply.

Arthur DeFever, designer of several new vessels says: "The seiner of today, which is noted by its rakish bow, conically shaped stem head, tapering to a fine entrance at the water line, appealing bow flare, forward-look side panels, modern superstructure, streamlined stack and slightly curved sheerline with low point near the stern, is good looking, and except for her seine net and skiff on the stern, she has a somewhat modern research ship appearance, or even scaled-up yacht aspect."

Fig 9. Lengthening a tuna purse seiner. Photo courtesy of National Marine Terminal, Inc.

Wooden hull construction, once predominant in the tuna fleet, has been entirely replaced by steel in new construction. A stern ramp for carrying the seine skiff for immediate launching avoids carrying the skiff on top of the net and semi-launching it on the grounds. The older method results in an actual towing situation, slowing the vessel's speed and restricting scouting operations, as well as causing wear and tear on the skiff. The seine skiff, itself, has kept pace with the development of the modern purse seiner, especially with respect to size. The skiff on one of these purse seiners may be 10 m long with 5.8 m beam and weigh 12.7 t. On some, a skin-cooled engine of 300 hp drives a 1.2 m diam. propeller through a 4½:1 reduction gear, others use twin diesels for power. The vertical gypsy, used for pursing floatline-ropes, is hydraulically driven (Arthur Yeend, personal communication).

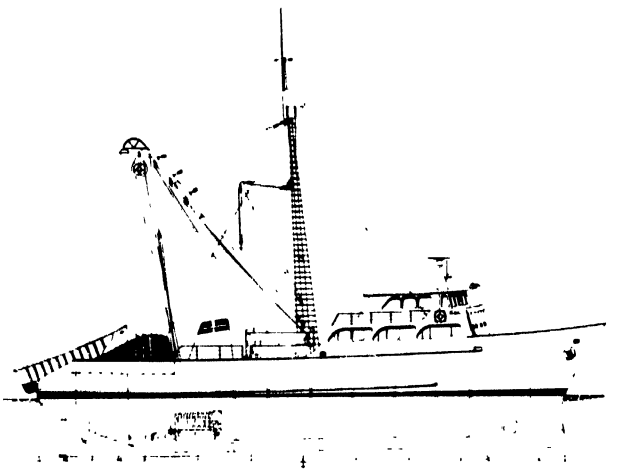

Fig 10. Outboard profile of purse seiner type of Vivian Anne. *Note in particular the bulbous bow, bow thruster, short drive shaft, and that the fish holds are forward of the engine space (After DeFever, 1968)*

Atop the bridge on several vessels may be found a small helicopter landing pad. Beneath the water line some include a bulbous bow for increased speed and a bow thruster for improved manoeuvrability while in the set. This latter may even be controlled through the autopilot, so that the seiner can maintain a constant heading even while dead in the water (Arthur Yeend, personal communication).

Control of vessel and gear during fishing operations has been simplified by consolidating most control operations into several strategic stations. The "fishing station" is now a standard, built-in convenience. It has an auxiliary set of full controls on the port bridge wing which permits the skipper to operate the vessel while looking down at the deck working area and out over the net. The hydraulic control console for the operation of nearly all of the after deck hydraulic machinery and power block is mounted in a position where the operator has full view of operations on the working deck. Seine winches may be separated for best locations of main functions and for easier maintenance. For example, the towline winch may be separately mounted on the port side in line with the setting of the net, thus eliminating one fair lead on the seine davit (Sverre Jangard, personal communication). The crow's nest may be fully outfitted and carry up to three men. From here, the mastmen, besides scouting for fish, may direct the operations of porpoise chasers by citizens band radio as well as coordinate deck operations with fish movements within the net, communicate with other vessels or spotter aircraft, or by way of another auxiliary set of controls, operate the vessel during the set.

Stern engine rooms (fig 10) with either single or twin main engines are included in several new boats by different builders. This arrangement offers the advantages of better weight distribution; short, one-piece tail shifts, and more efficient utilization of space (DeFever, 1968). Stacks are either offset to starboard on the aft deck just forward of the net platform or ducted forward to the more conventional stack location aft of the pilothouse. Skin-cooling, through the seiner's hull may be used instead of conventional heat exhangers (Arthur Yeend, personal communication).

While the power range of the older purse seiners was about 200 to 1200 hp, there are now purse seiners of 3200 hp or more. Many of these newer boats can sustain speeds of 15 kn, compared to older average of 10 kn.

Conventional ammonia refrigeration through brine is still employed although somewhat improved by the use of smaller wells (40 t capacity) with dual ammonia circuits in each well. Larger wells may have three circuits. Unloading is facilitated with more and larger unloading hatches.

Aft of the bridge deckhouse and on the after working deck is ample stowage room for up to three porpoise chaser boats ready for launching on their hydraulically-operated davits.

The modern purse seiners equipment may also include fuel oil centrifuges, hydraulic steering and pneumatic controls, and anti-roll devices. Included in electronic equipment is the newest Omega navigational system as well as the standard array of modern communications systems, radar, Loran, radio direction-finder, automatic pilot, echo sounders, and sometimes sonar.

Larger fishing vessels require longer trips to fill their capacity. Trips of long duration may adversely affect crew morale and therefore lower efficiency. Designers and builders have realized this and have designed modern tuna purse seiners with the comfort and morale of their crews in mind. Quarters are pleasant and well-appointed and may have built-in hardwood bunks and cushioned settees, ample closet and stowage space, carpeting and ample lighting. A stern engine arrangement makes all living quarters extremely quiet. Several toilets with stall showers and hot and cold water may be available for the crew with private toilets for the captain and engineer. Fresh water makers and ample water storage space have eliminated the water shortages of the past. A spacious, airy galley and dining room with large windows on three sides gives almost the impression of a fine waterfront restaurant. All living quarters are air-conditioned and some vessels even have high fidelity music piped to the various rooms.

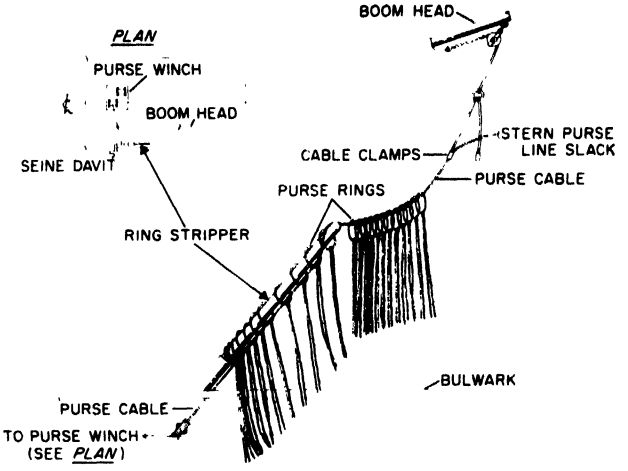

Fig 11. Ring stripper just before purse rings are placed on it. Drawing courtesy of Morris Whaley. Drafted by Kenneth Raymond

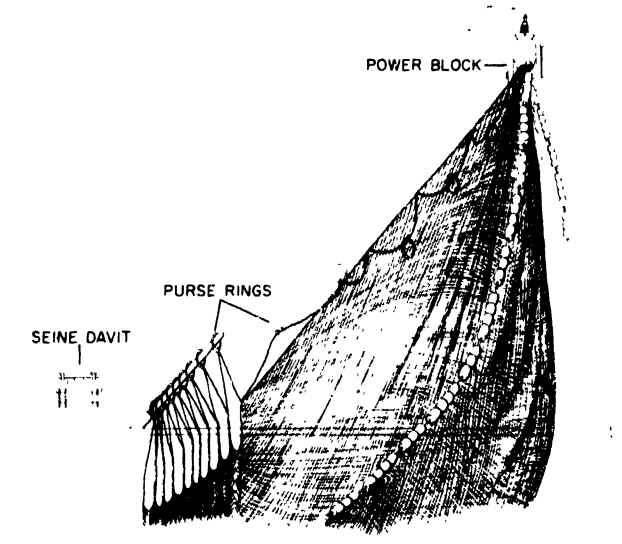

Fig 12. Ring stripper. Purse rings are pulled off as net is stacked. Drawing courtesy of Morris Whaley. Drafted by Kenneth Raymond

Purse seines and related gear

American tuna purse seines have changed little except in size for the last ten years. A typical purse seine at the start of this decade was 420 fm (765 m) long by seven 100-mesh deep strips of netting (McNeely, 1961). Nets carried by the newer purse seiners may be over 600 fm (over 1100 m) long by ten strips deep. While No. 42 thread (3543 Tex) is still used mostly in the main body of the net, some of the larger nets used when fishing tuna associated with porpoise are going to No. 48 and No. 54 (3720 and 4022 Tex).

Interest in tuna purse seine research has been stimulated by the Bureau of Commercial Fisheries development of the Hybrid Tuna Purse Seine. This experimental net features lighter webbing, lower hanging coefficients, tapered wings, floatline/leadline ratio = 1, gavels with breast pursing lines, and a setback of main purse rings from net ends. It has been very successful on "school fish" tuna, especially where erratic fish behaviour makes successful purse seining difficult. A complete report of this experiment is given elsewhere in this volume (Green, Jurkovich and Petrich).

There have been tendencies in new net construction of the last few years to introduce tapers in the wings and to be more generous in hanging in webbing, using hanging coefficients as low as 0.82 as opposed to the standard of 0.91 of ten years ago.

Net handling gear has remained essentially unchanged with the exception of the purse ring stripper, a patented method of handling the purse rings so that they and their bridles and the leadline do not obstruct working deck space or create a hazard during net stacking. The purse rings are, instead, threaded onto a steel shaft which is mounted rigidly just aft of the seine davit on the port bulwark. The operation of this device is as follows: the purse rings are hauled up to the seine davit and lifted with cable clamps from a double block hoist on a cargo boom in the usual manner. Now, instead of dumping rings and chain onto the deck, the bow portion of the loose purseline is placed in a groove running over the end of the shaft of the ring stripper. Tension is transferred from the bow cable clamp to the bow purseline

running over the ring stripper and the bow cable clamp is removed so that the rings are now hanging in the bight of the purseline between the end of the ring stripper and the stern cable clamp. This clamp is lifted until the rings slide forward on the purseline and spill down over the ring stripper (fig 11). The purseline is now removed from them as usual. The ring stripper is mounted at such an angle that, as the net is stacked, the rings are pulled off singly by the power block (fig 12) (Morris Whaley, personal communication).

"Porpoise fishing"

American tuna fishermen in the eastern tropical Pacific depend on porpoise for locating much of their fish (Perrin, 1968). Schools of yellowfin tuna usually occur in close association with large schools (up to 1500 animals) of two species of porpoise, *Stenella graffmani* (called "spotter" by the fishermen) and *Stenella longirostris* (called "spinner"). Because porpoise are air breathers and stay at the surface, the fishermen can spot them more easily at a distance. About half of the seine-caught yellowfin tuna from the eastern Pacific is captured from schools associated with porpoise (data furnished by Inter-American Tropical Tuna Commission). Yellowfin tuna make up approximately half the U.S. tropical tuna catch; the remainder is mostly skipjack (*Katsuwonus pelamis*).

The reason for the association of tuna and porpoise is unkown (Petrich, 1965) although some food-based relationship is suspected. Stomach-content analyses thus far carried out are inconclusive but indicate that they feed on some of the same things.

A new aspect of the tuna-porpoise association came to the fore when purse seiners began to replace pole-and-line boats in the tropical tuna fishery. The fishermen discovered that the association is very tight. They found that the fish seem to follow the porpoise very closely and that they can be herded by herding the porpoise, and that if even a few porpoise escape from the circle of the purse seine, all the fish might follow and be lost. These discoveries led to the development of a unique method of operations, called "porpoise fishing".

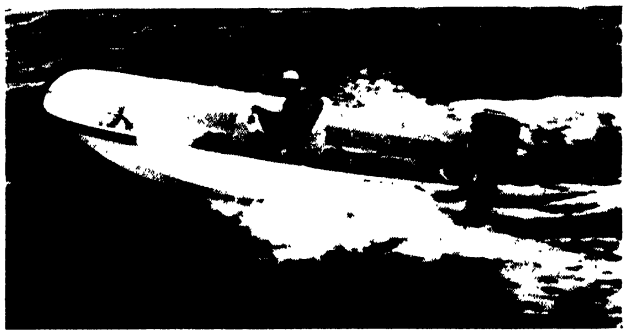

Fig 13. A light, powerful combination of skiff and engine is used for chasing and herding the porpoise. (After Perring, 1969)

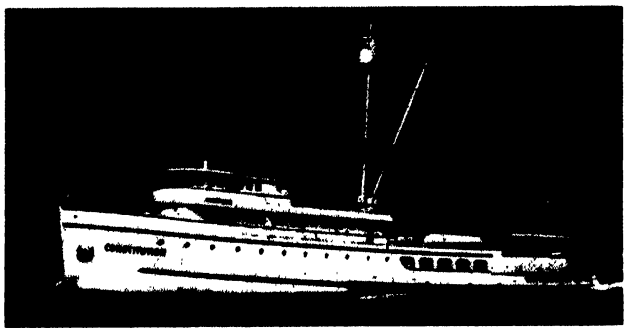

Fig 14. Seaplane lashed to canopy of tuna clipper Constitution. *Photo by Allied Craftsmen, courtesy of Vernon M. Brown*

The fishermen spot porpoise schools at the horizon with high-powered binoculars (up to 20 power) sometimes mounted on swivelling racks on the bridge. Most boats carry two such sets of binoculars. While the boat is on the tuna grounds, a constant "spotting watch" is kept during daylight with crewmen rotating the duty. In addition, a lookout with less powerful binoculars is posted in the crow's nest.

Feeding schools often can be detected over the horizon by sighting the birds (terns, boobies and frigate birds) which gather over them. When a school of porpoise is sighted, the boat runs up on it while the lookouts scan it for signs of fish. If the lookouts spot numerous "jumpers" (feeding fish breaking the surface), "shine" (flashes of reflected light from fish below the surface), or see a "blackspot" (dense school of fish below the surface), the boat prepares to set. If no fish signs are seen, the captain may still decide to set, gambling on the presence of unseen fish.

The boat stops, and the "chaser-skiffs" (also called "speedboats" or "pongos") are lowered overboard. These boats herd and direct the porpoise, slow them down if they are running, and tighten up the school. Most large seiners use two chaser-skiffs. A popular combination of skiff and engine is a 4.8 m fibreglass tri-hull using an 85 to 105 hp outboard motor. The skiff drivers are strapped in their seats and wear crash helmets (fig 13).

A "cork tender", a smaller skiff, is also lowered. This skiff follows the boat during the chase, and its driver tends the corkline during pursing and hauling.

The "fishing captain" (who may or may not be the boat captain) directs the chase and set from the mast. He has two-way radio contact with both chaser-skiff drivers.

Making a good set on porpoise is a fine art, and good "fishing skippers" are in high demand in the tuna fleet. The fishing captain directs and uses his chaser skiffs like shepherd does his dogs. When the school is headed properly, the captain sets his net.

When pursing is completed, the fish can no longer escape. Now the problem remains of separating the unwanted porpoise from the valuable tuna. For this purpose fishermen have developed an operation called "backing down". At the front end of the net (the end which goes overboard first, attached to the seine skiff) are several 30 fm lengths of line strung through 10 cm rings attached to the corkline by 0.9 m bridles. As soon as the front end of the net is picked up at the completion of the set circle and secured to the pursing davit, the man in the cork tender passes three or four of these lines to the deck, and they are pulled with the bow winch and secured.

This action causes the corks to bunch and a "balloon" to form in the back of the net. The net is then "dried up" (taken aboard) to approximately "half net" (farther if the catch is small). The net is strapped down, the rings are

secured, and backing down begins. The fishing captain directs from the mast. When the fish are near the boat and the porpoise at the far end of the net, he gives a signal, and the boat backs down, opening the net and at the same time sinking the corks at the far end.

Most of the porpoise are spilled over the corkline. The fish tend to swim upcurrent and into the balloon formed by bunched corks. Great care must be taken to avoid losing the fish as well as the porpoise. If the fish head toward the end of the net, the captain signals, and the engines are immediately put into forward allowing the corkline to rise to the surface. The cork tender is stationed at the end of the net to assist porpoise over the corkline.

After the backing down, the net is dried up to the bunt (reinforced section at the back of the net). The bunt is "sacked up", that is, webbing in excess to that needed to hold the fish is gathered up from the bottom and tied down. The seine skiff comes alongside, and the corkline on the side of the "bag" opposite the boat is secured to the skiff's rail. A portable rack is hung on the skiff, and a crewman stands in the rack and assists the remaining porpoise over the corkline. The bag is then sacked-up farther, and the fish are brailed aboard.

The Bureau of Commercial Fisheries has in recent months begun research to develop improved methods of eliminating mortality of porpoise in the fishing operation.

Fish finding

Visual scouting, whether it be from the bridge, crow's nest or aircraft, is still the most important method for finding tuna in this fishery. After a fishing area is chosen by experience with seasonal movements of fish, current contacts with other tuna boats, etc., all available crewmen act as lookouts whenever the vessel is on fishing grounds. During daytime they search from vessel to horizon with high-powered binoculars or with the naked eye for such signs as birds, whales, porpoises, basking sharks, floating objects or surface disturbances from tuna. If night fishing is done during the dark of the moon they search the water for bioluminescence caused by tuna presence. The glow may be intensified by stimulating the tuna to increased activity with occasional sweeps of a searchlight.

An airborne observer can be a useful adjunct to the fishing operation in two ways: (1) he can spot fish at great distances from the vessel because of the aircraft's height and range of operation. Under ideal conditions (sun overhead and clear skies), an observer flying at 182 m can scan a swath of ocean 60 miles wide as compared to 19 miles for an observer in the vessel's crow's nest at 18.2 m, having a good view of the fish and their position relative to the vessel, or to the porpoise school in the case of "porpoise fishing". (2) He can "set the boat", telling the vessel when and where to release the net and how to manoeuvre in completing the circle of the set.

The first use of a ship-based aircraft in the tuna fishery was in 1946. A helicopter (Sikorsky S-55) was taken out on the *Espiritu Santu*, but proved too expensive to maintain (personal communication from Robert Jones). In the 1940's some boats began to carry small seaplanes (fig 14). By 1952, 21 seaplanes were in use in the fleet, but a period of economic hardship cut the number until by 1955 there were none left.

In the early 1960's, after conversion of the fleet to seiners and after economic improvement, interest in ship-based aircraft was renewed, and since then helicopters have been in sporadic use, two or three being in operation every fishing season. In very recent years, with the advent of very large seiners (546 to 1,900 t capacity), the use of a helicopter has become economically more feasible, and some new designs include built-in helicopter pads.

There are advantages and disadvantages in the use of both fixed-wing aircraft and helicopters. A helicopter has the great advantage that it can take off from and land on the vessel, but is expensive and extremely difficult to maintain properly, especially under at-sea conditions, and is easily crippled if forced to land in other than flat-calm seas conditions. A seaplane has greater range than a helicopter (up to 7 h) and is more dependable and economical to maintain, but it must be lowered into the water to take off and be picked up after it lands. If a simple method of launching and recovery, perhaps with a special large boom, could be developed, the seaplane, because of its range and dependability, would seem to be the better-suited craft for use at sea. The chronic problem of rapid metal corrosion due to prolonged exposure to salt-laden air could easily be eliminated aboard the large vessels through a system for washing down with fresh water.

The use of shore-based aircraft spotting services has proven more cost effective than maintaining aircraft aboard ship. A percentage of the value of fish caught with such assistance is usually paid to the spotter pilot. The service is limited, however, by the distribution of adequate shore facilities and the range of the aircraft used.

Sonar has seen little use in this fishery. Of the few purse seiners carrying it, we know of no one who uses it for making sets on tuna. Our fishermen, inexperienced with this gear, are loath to make sets on anything whose species or size cannot be identified. A set on a school of mackerel or undersized tuna may result in a "christmas tree" (purse seine loaded with gilled fish).

Several seiners have had navy surplus, bathythermograph (BT) winches installed in a cooperative research project with the Bureau of Commercial Fisheries. BT data collected during their fishing operations established a direct relationship between the depth and temperature gradient of the thermocline and the success of purse seine sets (Green, 1967). This fact has been increasingly used in searching tactics for tuna. The use of the more modern expendable BT system is now beginning to replace the older mechanical type.

Automatic water temperature recorders with read-outs conveniently located in the pilot house are replacing the use of the engine room water intake temperatures for fish scouting. All tuna fishermen have learned through experience the optimum sea surface temperature ranges of the tunas that they fish for and use this knowledge in their scouting tactics. Temperature changes are used to locate oceanic "fronts"—lines of convergence of different water masses. Tuna fishermen often follow these fronts as they scout for fish.

Expansion of the fishery

Along with technological development of the American tuna purse seine fleet in the 1960's has come major

changes in the distribution of production centres and fishing areas.

Production centres. As late as 1953, the southern California canneries accounted for 87 per cent of the national pack. In recent years the situation has changed due to the attraction of processors and vessels to Puerto Rico. Processor interest in Puerto Rico stemmed from availability of low cost labour, proximity to eastern markets, and tax incentives. In 1953, tuna canning operations started in Puerto Rico with the establishment of one packing plant. At present, four canneries operate there.

As canning in Puerto Rico increased, tuna vessels from southern California transferred there also. The logistics of operating there, however, favoured only the larger vessels. In 1958, ten bait-boats with a combined capacity of 3,840 t, 11 per cent of the total U.S. tuna fleet's capacity (both bait-boats and seiners), were based at Puerto Rico. Since 1966, an added incentive to the large purse seiners has been the proximity to the burgeoning tuna fishery off the west coast of Africa. In 1969, 21 purse seiners totalling about 15,015 t capacity or 31 per cent of the total fleet's capacity were based there. Of these, 15 vessels were among the new additions to the fleet since 1961 (section 4.1.1). At present, no U.S. bait-boats operate from Puerto Rico.

Of the U.S. total annual tuna pack in 1967, Puerto Rico produced about 32 per cent, southern California 44 per cent, the rest of the continental U.S. 12 per cent and American Samoa and Hawaii 12 per cent (Forbes, Stevenson and Baldridge, 1969).

Regulations and shift from eastern tropical Pacific. In 1966, for the first time, conservation measures for yellowfin tuna in the eastern tropical Pacific recommended by the scientists of the Inter-American Tropical Tuna Commission (IATTC) were adopted by member nations. These recommendations included a "catch quota" (72,163 t in 1966). That year the closure date was September 15. After this date, no vessels were to leave port to fish yellowfin, but more than 75 per cent of the fleet was still at sea, unloaded, and fishing therefore continued in almost full swing for most of the rest of the year.

In 1967, however, the closure date was June 24th, and the fleet suddenly found itself faced with the alternatives of fishing exlusively for skipjack or going farther afield in search of yellowfin outside the IATTC regulatory area. Three vessels chose to seek yellowfin on the west coast of Africa in the Gulf of Guinea, where tuna vessels, mainly bait-boats, of France and other nations, have long operated. The three vessels, the *Caribbean*, the *Southern Seas* and the *Day Island*, fished as a group and shared the spotting services of a helicopter (Simmons, 1968). About 1,365 t of tuna were caught in two months of fishing (unpublished data furnished by IATTC) including 81 t of yellowfin "on porpoise" (*Delphinus delphis*).

In 1968, the closure date again came in June, and spurred by the success enjoyed by the three vessels that visited Africa the previous year, eight vessels went to the Gulf of Guinea. In 1969, closure came even earlier, in April, due to the increased capacity of the fleet, and 23 vessels went to Africa. In 1970, closure came in March, and the fleet is still larger, so the move to the Atlantic can be expected to be still greater.

Some vessels of the U.S. fleet have begun fishing far offshore, outside of the regulated area after the closure of the yellowfin season. Interest is being shown in other areas, including the Indian Ocean and the central and western Pacific Ocean. A cannery-financed exploratory trip, in the latter areas, by one purse seiner was carried out in the summer of 1970.

PROSPECTS FOR THE FUTURE

Total world demand for tuna has increased rapidly in recent years. World consumption of tuna and tuna-like species (in round weight) increased from 0.99 million t in 1958 to 1.4 million t in 1968 (FAO, 1969). *Per capita* consumption of canned tuna in the U.S. has increased from an average of 0.49 kg to 1.1 kg reported in 1969 (Forbes, Stevenson and Baldridge, 1969). This rising trend is expected to continue at a higher rate because of increases in population and, more importantly, standard of living.

Bell (1969) estimates that world consumption of tuna would double in each of the next two decades if supplies are adequate and there is no rise in prices. He estimates, however, that the world's oceans can supply only about 2.6 million t of tuna on an annual sustainable basis, and that prices and costs of tuna will double by 1990, with a world catch of about 2.1 million t, and triple by the year 2000 when the world's maximum sustainable yield is reached. This assumes that overfishing will be prevented as each of the stocks are exploited.

The American tuna fleet, since its inception, has been constantly responding to both foreign and domestic developments affecting their operations and markets and will continue to do so. The present trend to new construction of large purse seiners shows no signs of abatement. At the end of 1970, total U.S. tuna fleet capacity will be about 58,695 t. While many of these larger vessels are designed with the potential of worldwide operations in mind, it must be expected that they will also compete with the smaller, older vessels on the closer, traditional fishing grounds of the eastern tropical Pacific. With the entry of the newer vessels in this fishery, and the yellowfin season being progressively shortened, many smaller boats, which have no other place to fish, may be forced out of business as competition is intensified.

Expansion of the newer vessels of the U.S. fleet into waters outside of the yellowfin regulatory area, however, is certain to continue. Prospects may include the central and western Pacific Oceans and Indian Ocean. Catch per unit of effort cannot be expected to remain as high as present levels as new resources, such as central Pacific skipjack are relied upon. Although the stocks of these fish may be high, they are diffusely distributed, and with present technology, difficult to find and harvest. Production costs will therefore increase.

Competition from foreign tuna fisheries, using lower cost labour, is apt to increase. Japan, now experimenting with purse seining for tropical tunas in the eastern Pacific may decide to enlarge that segment of her long-range tuna fleet. Ecuador is proceeding with plans to build a tuna purse seine fleet with financing from the United Nations' International Bank for Reconstruction and Development.

In spite of developments of the past ten years, purse seining methods and gear have remained basically the same. But, with longer-range operations, higher production costs, and competition with low-cost labour, the U.S. fleet may be forced to raise its level of technology in the years to come. Improved refrigeration methods and partial processing at sea may be able to increase the value of the catch. Loading the catch aboard should become more mechanized to avoid loss of time on the fishing grounds and similarly more mechanized offloading, such as containerized fish holds, can reduce turn around time by as much as two to three days. Diesel electric or turbine electric main drives should be considered (DeFever, 1968). Net handling may be improved by developing methods of mechanized net stacking. The use of articulated cranes instead of the old style mast and boom rigging may further speed the fishing operation. The purse seine, itself, has only recently come under scrutiny for possible improvements in design (Green, Jurkovich and Petrich, 1970). Methods for quickly changing the hang-in percentage and depth of nets are waiting to be tried (Petrich, 1968). Nets, in the future, may be of more highly specialized designs for particular fishing conditions.

As tuna inevitably become scarcer we must expect to develop and improve scouting and fish finding methods. Sonar may eventually play a more important role in the U.S. tuna fleet. We may expect to see refinements in the use of ship-based aircraft including the development of airborne, automatic sensors. Work has already begun in the use of satellites to locate fishing areas.

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Les Tactiques de Recherche et de Pêche à la Senne Coulissante des Thonidés

R. Lénier

Searching and catching tactics for tuna purse seining

There is a trend for purse seining to replace the other methods used for tuna fishing, in particular long line and pole-and-line fishing. The various tactics for tuna locating and catching are described, i.e. fishing with the assistance of a pole-and-line tuna boat or with use of a baiting skiff, seining without bait on visually sighted surface schools or those concentrated by feeding on anchovy, and lastly around floating objects (in this case with the use of radar). Detection equipment (echo-sounders and sonars) are providing an aid which, although limited at present, will probably increase during the forthcoming years.

Metodos de busca y captura de atun con redes de cerco de jareta

La red de cerco de jareta tiende a sustituir otros métodos de pesca del atún en particular el palangre y la caña y línea. Se describen diversas maneras de localizer y pescar atún, entre ellas la practicada con el auxilio de un barco atunero que pesca con caña y línea o con el empleo de un bote de macizar, pesca al cerco sin cebo de cardúmenes avistados en la superficie o de los que se concentran para alimentarse de anchoas y, finalmente, alrededor de los objectos flotantes (en este caso empleando radar). El equipo de localización (ecosondas y sonares) es un auxiliar cuyo uso, aunque circunscrito en la actualidad, probablement aumentará en los años próximos.

LORS du dernier Congrès des Pêches de la FAO qui s'est tenu à Londres en mai 1963, nous avions présenté un document sur la détection et la localisation des bancs de poissons. Ce document avait surtout pour objet de favoriser, pour les pêcheurs, l'identification des échos enregistrés sur les bandes des sondeurs. Chaque espèce de poissons, aussi bien benthiques que pélagiques, donnait une image différente sur ces bandes. Aujourd'hui, les pêcheurs sont entièrement familiarisés avec les échos obtenus et ils reconnaissent grâce à leur expérience les espèces que le sondeur déctecte. Il nous semble donc superflu de revenir sur cette matière.

Notre propos sera particulièrement axé sur les techniques utilisées pour la capture des thondés et particulier sur la pêche à la senne coulissante, méthode qui tend à supplanter aujourd'hui l'emploi de la canne et de l'appât vivant.

Cependant, avant de passer à la description de cette méthode de pêche, il nous semble nécessaire de mesurer les progrès techniques réalisés par l'industrie électronique internationale depuis le Congrès de Londres.

Dans ce domaine, les Britanniques ont fait un effort particulier et expérimentent actuellement divers appareillages dont un "bifocal sector scanner" qui permet de remarquables observations concernant tant le chalut en action que son environnement. Mais il s'agit là de techniques de pointe encore en cours d'expérimentation.

Les appareils de détection ont été considérablement perfectionnés autant sous le rapport sensibilité que robustesse. Il était en effet particulièrement important de mettre à la disposition ces navires de pêche des organes dont la manipulation n'était pas trop délicate et surtout exempts de panne et de dérangement dans la limite où cela était possible.

De remarquables progrès ont été aussi réalisés dans le domaine des netsondes dont l'emploi tend à se généraliser pour les chaluts pélagiques et semi-pélagiques.

D'une manière plus générale, il est intéressant de noter que c'est la pêche traditionelle aux harengs qui a permis, par l'adoption de toutes les aides à la navigation et à la pêche mises à sa disposition par l'industrie électronique, de modifier totalement la routine ancestrale des pêches.

Par ailleurs, au cours de ces dernières années, le radar a reçu une application imprévue et sert aujourd'hui comme moyen auxiliaire pour la recherche des thons.

A l'origine les pêcheurs de thons ont remarqué que ces poissons se rassemblent dans leur course capricieuse et vagabonde autour des épaves flottantes sous lesquelles ils trouvent généralement une nourriture abondante. Leur gloutonnerie les conduit ainsi à se concentrer très souvent dans le voisinage d'épaves flottantes constituées par des simples billes de bois, des tas de paille, ou d'algues flottantes et même autour des cétacés et souvent des tortues.

Il s'ensuit que les thoniers en exercice de pêche, surtout dans les mers tropicales, recherchent maintenant au radar la présence d'épaves flottantes et on a constaté des pêches importantes réalisées autour de ces dernières.

Nous donnerons ici les différentes tactiques de pêche à la senne pratiquées par les pêcheurs français sur les côtes africaines. Nous avons pour cela fait des emprunts à un de nos confrères, Monsieur Le Rouzic, qui a eu la bonne fortune de pouvoir rassembler les documents sur les méthodes employées par les pêcheurs de thon. Je tiens à le remercier ici pour l'aide précieuse qu'il m'a apportée.

GENERALITES

Les thons représentés par plusieurs espèces de caractères biologiques différents, mais de comportements à peu près identiques, se rencontrent en abondance sous toutes les latitudes comprises entre le tropique du Capricorne et celui du Cancer. Ils remontent dans les eaux tempérées suivant les saisons et le réchauffement des courants.

Ces espèces, à conservation facile, sont à l'origine d'une pêche commerciale très importante. Les Japonais ont été longtemps orfèvres dans la pratique de cette pêche. Ils semblent aujourd'hui abandonner la pêche à la "long line" pour suivre le mouvement actuel qui se caractérise par l'emploi de la senne coulissante et par la recherche des concentrations de thonidés à l'aide des appareils électroniques.

La pêche à la "long line" a été peu pratiquée par les Américains, et pas du tout par les Français, Basques ou Bretons. Cette pêche représentait en raison des dégats causés par les prédateurs aux poissons pris aux hameçons un travail de boucherie aussi important que la pêche proprement dite. Sur le plan social, les habitudes et les

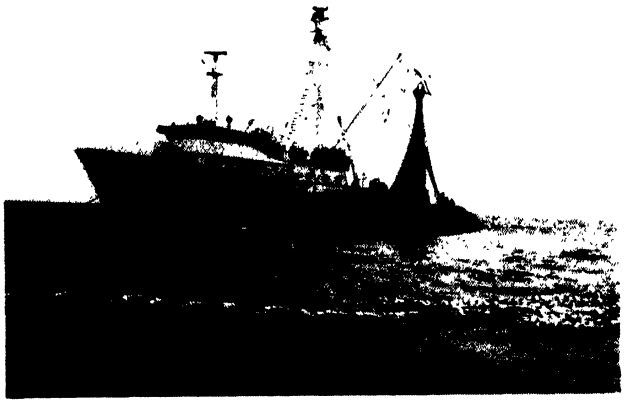

Fig 1. Thonier seineur congélateur Trévignon *effectuant ses essais de pêche*

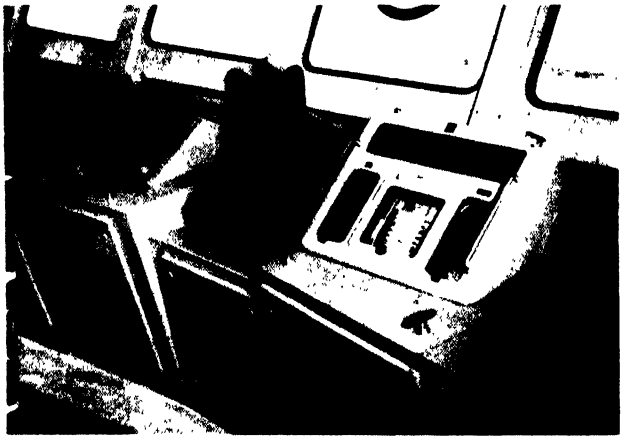

Fig 2. Equipement de detection (sondeur et sonar) dans la passerelle du thonier senneur Trévignon

coutumes des pêcheurs européens ne permettaient pas d'assurer la rentabilité de la pêche. Cette méthode tendra vraisemblablement à disparaître, pour être rapidement et avantageusement remplacée par la pêche à la senne coulissante (fig 1). Les pratiques routinières de recherche des bancs de poissons, dont les moeurs grégaires permettent des concentrations importantes et dont la gloutonnerie et les caprices de vagabondage sont connus, restent toujours d'actualité. Mais il paraît aujourd'hui impensable que les navires thoniers n'utilisent pas au maximum les aides électroniques pour une pêche rentable, les investissements dans ce domaine étant toujours payants (fig 2).

TACTIQUES DES PECHEURS THONIERS FRANÇAIS POUR LA CAPTURE DES BANCS DE THONIDES

Nous citerons seulement pour mémoire la pêche des thons à la canne, que les pêcheurs basques avaient rapportée d'Amérique il y a un peu plus d'une décade; cette pêche consistait essentiellement dans l'amorçage des bancs de thons à l'aide de petits poissons vivants: sardines, sardinelles, anchois, etc. Seul cet appâtage a été conservé pour la pêche à la senne tournante.

Pêche à la senne avec l'aide d'un thonier canneur

On peut la pratiquer de plusieurs façons. En principe quand un thonier pêchant à la canne croit, à l'aide de méthodes visuelles, être sur un banc de poissons, il lance ses appâts vivants et tente de rassembler le banc à proximité de sa coque. Les prises à la canne lui permettent de situer exactement l'importance du banc qu'il cherche à contrôler à l'aide de son sondeur ou de son sonar. Un autre thonier encercle alors avec sa senne le navire appâteur qui se dégage ensuite par dessus les flotteurs après la fermeture complète du filet.

Dans de bonnes conditions cette méthode peut permettre la capture de bancs importants retenus par l'appât vivant jeté avec prodigalité.

Pêche à la senne sur la vedette d'appâtage du senneur

C'est le cas le plus fréquent. La quasi totalité des thoniers senneurs congélateurs français sont ainsi équipés d'une vedette à vivier qui sert à la capture de l'appât à l'aide d'un petit filet tournant appelé "bolinche". Lorsqu'un banc de thon a été repéré puis approché, cette vedette est mise à l'eau avec son vivier rempli d'appât prélevé sur la réserve existant dans les grands viviers du thonier. Elle amorce alors le banc de thons dans les mêmes conditions que l'aurait fait un "canneur" et lorsqu'elle estime, à vue ou à l'aide d'un petit sondeur que le banc est suffisamment dense, bien groupé et suffisamment en appétit, elle demande par talky-walky au navire principal d'effectuer l'encerclement.

Dans le cas du travail à la senne sur appâtage, l'encerclement se fait assez lentement (4 ou 5 noeuds) pour éviter d'affoler le poisson et pour laisser au filet le temps de descendre profondément. Il n'y a pas de tactique bien définie, elle est conditionnée par les éléments du moment, en fonction du courant et des vents; il faut éviter que la vedette appâteuse ne dérive pas trop vite vers les flotteurs et surtout qu'elle ne les atteigne pas avant la fermeture totale du filet. Ceci afin d'éviter que le poisson s'affole, vienne en contact avec le filet et sonde pour trouver une issue par le fond.

Pêche à la senne tournante à la volée, sans appâtage, sur les "rouges"

La terme "rouges" désigne principalement des bancs d'anchois, encerclés en surface par les thonidés et se groupant pour faire face à leur attaque jusqu'à former une masse de couleur brune. Les anchois en viennent à se monter les uns sur les autres sous l'influence de la peur et leur sang rougit l'eau en surface. Le problème pour le senneur est d'intervenir rapidement dès la formation d'un rouge car la curée ne durera que quelques minutes pendant lesquelles il faudra procéder au plus vite à l'encerclement et au coulissage. C'est surtout par des méthodes visuelles que cette présence de thons est décelée. Les Basques particulièrement, par temps favorable et mer calme, ont des méthodes ancestrales et une sorte d'atavisme particulier pour repérer les bancs d'anchois poursuivis par les prédateurs. Il faut encercler très rapidement le rouge en donnant au navire toute la vitesse possible, car dès que la boule d'anchois est épuisée, les thons se dispersent très rapidement pour partir à la recherche d'une autre concentration.

Cette pêche sur les rouges, malheureusement assez rare, est très productive, le thon gavé étant échauffé par la curée et perdant toute prudence.

Pêche à la senne tournante à la volée sur "balayas"

Le poisson joue en surface ou juste sous la surface ne faisant qu'une petite risée ou "balbaya", se déplaçant souvent très rapidement; c'est la pêche qui demande le plus d'habileté, le plus de tactique et le plus de dons d'anticipation. Il faut deviner en fonction du vent, du courant, de la nourriture plus ou moins abondante qu'il accompagne, dans quel sens le banc de thons va se diriger. Le pourcentage de réussite est assez faible et est souvent l'effet du hasard ou de la chance. On cherche à travailler à vue en appréciant si dans le balbaya, où les poissons sont souvent mélangés, se trouvent des thons d'une taille marchande. Cette appréciation se fait à vue d'un point surélevé (nid-de-pie) ou par le repérage de quelques poissons qui peuvent sauter hors de l'eau.

C'est plus particulièrement dans ce genre de pêche que l'on a recours aux bruiteurs divers ou autres procédés pour empêcher le poisson de rompre l'encerclement; enclumes à main sur le pont ou enclumes à air comprimé sur la quille, pétards, fluorescéine pour teindre l'eau dans la zone névralgique de la coulisse par où le poisson s'évade le plus souvent.

Lorsqu'ils n'arrivent pas à apprécier la densité du banc ou sa qualité, les patrons se décident souvent à passer au travers du balbaya pour le jauger au sondeur vertical. Ce passage leur permet quelquefois de relever des échos qui sont la preuve de la présence de gros poissons dans le banc.

La meilleure tactique sur les balbayas très mobiles est de larguer le skiff avec l'extrémité du filet, de telle sorte que l'encerclement terminé le banc continue de se déplacer dans la senne, dans le même axe que le navire. De cette façon il recontre d'abord le barrage de filet et prend, pour trouver la sortie, un certain temps que l'on met à profit à bord pour coulisser très rapidement.

Pêche à la volée sur les "logs" ou épaves

Comme nous l'avons déjà signalé, il s'agit le plus souvent en Afrique de billes de bois ou "logs", de tas de paille ou îles de roseaux en dérive. Ces épaves ont la particularité d'être associées à la présence de plancton, minuscules crevettes et petits poissons qui attirent les thons.

Le plus souvent on encercle les épaves sans avoir constaté d'apparence de thon mais parce que l'on sait qu'il existe des probabilités assez grandes de présence de thonidés. Des coups extraordinaires ont été réalisés dans l'Atlantique et le Pacifique sur des logs. Ils sont malheureusement rares mais leur productivité peut être très grande: on a vu ramener de 80 à 200 tonnes dans un seul coup de filet.

CONCLUSION

Les méthodes visuelles sont encore largement utilisées dans la recherche des thonidés. Cependant l'emploi du sondeur et du sonar tend de plus en plus à augmenter les possibilités de repérage des thons. De nombreuses expériences ayant démontré que, malgré l'absence d'indices en surface, il pouvait exister des concentrations importantes de ces poissons à des profondeurs plus grandes, c'est en étudiant au moyen des appareils de détection le mode de montée en surface des thons que nous augmenterons nos connaissances sur le comportement de ces espèces; il en résultera des captures plus régulières et plus abondantes.

Japanese Tuna Purse Seining off West Africa

S. Sugano, S. Yamamura

La pêche du thon à la seine coulissante par les japonais au large de L'Afrique de l'ouest

A la suite d'observations effectuées par des navires japonais pêchant le thon à la palangre et à la canne concernant la présence en surface de bancs d'albacores, listaos et melvas, la compagnie a commencé en novembre 1964 la pêche du thon à la seine coulissante au large de l'Afrique de l'Ouest, selon la technique japonaise classique à deux bateaux. Cette technique nécessite pour chaque filet un ensemble de pêche formé par trois ou quatre bateaux de 85 à 145 tx environ. Le traitement, l'entreposage et le transport de la pêche demandent également un navire-mère congélateur (1700 tx environ) et des transporteurs (400 à 650 tx environ). L'opération, qui avait débuté avec un ensemble de pêche, a atteint son maximum en 1968 avec quatre ensembles de pêche à deux bateaux et un seineur isolé (soit un total de 20 bateaux), pour être réduite quelque peu en 1969 en raison de l'insuffisance des prises. On projette de poursuivre l'opération. Bien que le thon puisse être trouvé à longueur d'année dans différents secteurs, on a constaté que la meilleure saison avait lieu de janvier à juillet. Des essais sur maquettes approfondis ont été réalisés pour améliorer le dessin de la seine qui n'est cependant pas encore pleinement satisfaisant. Les limites des essais sur maquettes à petite échelle (1:200) apparaissent dans la divergence des valeurs obtenues pour la vitesse de plongée, notablement plus faible pour l'engin de taille normale en comparaison des performances observées sur la maquette. Les dimensions du filet ont été augmentées pour atteindre, en 1966, les dimensions maximales de 2.325 m pour la ralingue de flotteurs (3.360 m de filet étiré) et de 288 m et 345 m pour la chute étirée de la poche et de corps principal respectivement.

Los japoneses pescan atun con redes de cerco en aguas del oeste de Africa

Con objeto de aprovechar las observaciones que los barcos japoneses que pescan con palangres y con caña y línea habían hecho de cardúmenes de superficie de rabil, listado y melva, una empresa armadora japonesa inició en noviembre de 1964, en aguas del oeste de Africa, la pesca del atún con redes de cerco, siguiendo la técnica tradicional japonesa de las dos embarcaciones. Esta técnica requiere para cada red tres o cuatro barcos de 85 a 145 toneladas brutas para elaborar y almacenar y transportar la captura. Se necesitan además un buque madre congelador (de unas 1.700 toneladas brutas) y barcos transportadores (de unas 400 a 650 toneladas brutas). La pesca se inició con un grupo que empleaba una red; alcanzó en 1968 el maximo de cuatro grupos de dos barcos por red más un barco cerquero sólo (20 barcos en total) y se redujo algo en 1969 debido a lo reducido de las capturas. Se intenta continuar esta clase de pesca. Aunque el atún se captura en diversos lugares durante todo el año, la mejor época es desde enero hasta julio. Se hicieron abundantes ensayos de modelos para mejorar las formas de la red, pero ésta no es todavia completamente satisfactoria. Se ponen de relieve las limitaciones de las pruebas modelos a pequeña escala (1:200) por la discrepancia observada en la velocidad de hundimiento, que es muy inferior en la red normal que la que indicaba el funcionamiento del modelo. Se aumentaron las dimensiones de la red y en 1966 alcanzaron el máximo con una longitud de relinga de corchos de 2.325 m (3.360 m de paño estirado) y una altura estirada de copo y cuerpo principal de 288 y 345 m, respictivamente.

IN 1956 Japanese tuna longliners sailed to West Africa and started fishing. Nichiro Gyogyo Kaisha Limited dispatched tuna longliners of 500 GT and confirmed that these areas have abundant resources of skipjack and yellowfin.

In contrast, U.S. tuna purse seiners, operating in the sames areas, on trial in 1960, had poor catch rates. At that time, French and Spanish fleets, which were engaged in operations off North Africa, moved southward during their off-season, from January to March and began fishing operations based in Dakar, Freetown and Abidjan. Their fishing was done mainly by pole and line, and their results were good. Most large boats of these countries have been operating all year off West Africa since 1959.

Due to operations by our longliners since 1957 and foreign flag boats mentioned above, we built 6 pole and line boats (240–304 GT) equipped with brine tanks and dispatched them to West Africa for 3 years (1962–1964), hoping that pole and line fishing would be suitable for catching skipjack and yellowfin. During the first year we could not get good catches owing to unfamiliarity with this kind of fishing, but in the second year, fishing efficiency improved and continued year by year. Consequently, the landings of a boat per annum mounted from 1,600 to 2,700 t (skipjack 60 per cent, yellowfin 20 per cent, others 20 per cent) and this became a stable enterprise. Throughout pole and line operations, many surfacing schools of skipjack and yellowfin were observed, but these schools were not attracted by bait. We judged that it might be possible to catch these schools by purse seining, so we decided to try this method.

FISHING METHODS

There are two kinds of tuna purse seining: one is two-boat purse seining mainly for catching bluefin in the Pacific Ocean off Northern Japan; and the other is one-boat purse seining such as U.S. purse seining for catching skipjack and yellowfin in the Eastern Pacific Ocean.

When we started fishing off West Africa, we considered the following points:

(a) As the fishing areas for purse seining off West Africa were unknown to us, a fishing method which secures certain catch should be adopted.
(b) American seiners had not obtained good results on trials with conventional fishing gear from the Eastern Pacific Ocean.
(c) There were many things unkown to us in the American purse seining system, and it was impossible to secure skilled crews for this fishing method.
(d) Japanese two-boat purse seining had been an effective method to capture fast-moving bluefin.
(e) It was necessary for us to have a freezer mothership and some freezer carriers.

After consideration of the above points, we decided to form a fleet consisting of two-boat purse seiners, a freezer mothership and freezer carriers.

DEVELOPMENT OF FISHING OPERATIONS

In the first stage, 1964–1965, we had a fleet consisting of the following vessels:

Freezer Mothership: No. 2 Chichibu-Maru (1,698 GT)
Main Boat: No. 81 Kuroshio-Maru (145 GT)
Sub Boat: No. 82 Kuroshio-Maru (145 GT)
Attendant Boats: Ryoan-Maru (85 GT)
Seiryu-Maru (85 GT)
Freezer Carriers: No. 3 Haruna-Maru (641 GT)
No. 18 Kuroshio-Maru (48 GT)

This fleet departed in August 1964 from our Kurihama Fishing Base and arrived at Tema, Ghana (where our pole and line boats had a base) at the beginning of November. On November 13th 1964 our fleet started fishing off Point-Noire, and obtained good results. After that, our fleet operated in various areas such as around the Island of Sao Thome, off Tema, off Cape Three Points, off Monrovia and off Freetown, and got a total catch of 3,782 t (skipjack 41.4 per cent, yellowfin 53.6 per cent, others 5.6 per cent) up to November 1965. But this quantity was too small for the freezing capacity of the mothership and the carrying capacity of the carriers, so we needed an increase in our catcher-boat fleet.

In the second stage, 1966–1968, we decided to increase the number of boats and added the following seiners and freezer boats to our fleet:

One net unit, owned by Kawajiri Gyogyo Kaisha, Limited, Rikuzentakata.

Main Boat: No. 52 Hakuryu-Maru (90 GT)
Sub Boat: No. 53 Hakuryu-Maru (90 GT)
Attendant Boat: No. 51 Hakuryu-Maru (89.1 GT)

One net unit, owned by Aizawa Gyogyo Kaisha, Limited, Ishinomaki.

Main Boat: No. 10 Seisho-Maru (90 GT)
Sub Boat: No. 13 Seisho-Maru (90 GT)
Attendant Boats: No. 21 Seisho-Maru (89 GT)
No. 22 Seisho-Maru (89 GT)

Sub-Freezer Mothership: Haruna-Maru (1,427 GT)

Our fleet, consisting of 3 two-boat purse seine units began regular seining operations in July 1966. Many schools of yellowfin were observed in the Gulf of Guinea and southward, and these fishing areas southward of the Island of Sao Thome and off Tema produced a total catch of 10,783 t (skipjack 22.6 per cent, yellowfin 73.5 per cent, others 3.9 per cent). Consequently the average catch per pair amounted to only 3,594 t, but as high-priced yellowfin occupied more than 70 per cent of the total catch the fishery was profitable.

Later, we dispatched another two-boat purse seine unit in October 1967 to join our fleet, consisting of:

One net unit, owned by Aizawa Gyogyo Kaisha, Limited, Ishinomaki.

Main Boat: No. 17 Seisho-Maru (90 GT)
Sub Boat: No. 18 Seisho-Maru (90 GT)
Attendant Boat equipped with brine tank: No. 25 Seisho-Maru (265 GT)

In spite of this new recruitment to the fleet, we did not make good catches for one year starting in July 1967, due to poor fishing conditions. The total catch of 4 pairs of purse seiners was 9,903 t (skipjack 34 per cent, yellowfin 57 per cent, others 9 per cent), and the average catch per pair amounted to 2,829 t only.

In July 1968, we dispatched a one-boat purse seiner, No. 8 Fukuho-Maru (90 GT) and an attendant boat equipped with brine tank, No. 83 Shofuku-Maru owned by Fukuho Suisan Kaisha Limited, Narao, Nagasaki. Besides our fleet, U.S. type seiners No. 82 Genpuku-Maru (499 GT) owned by Toyo Gyogyo Kaisha, Limited, Nagasaki and No. 55 Hakuryu-Maru (499 GT) owned by Kawajiri Gyogyo Kaisha Limited, Rikuzentakata were dispatched to West Africa and fished in cooperation with us.

In this year, the number of boats belonging to our fleet reached the maximum with 4 pairs of two-boat purse seiners, 1 one-boat purse seiner, 2 freezer motherships and others for a total of 20 vessels.

However, we had not experienced good fishing during the period from July 1968 through June 1969. This was in part due to some troubles with No. 8 Fukuho-Maru which turned back to Japan in the middle of the fishing season. In consequence, the total catches of the 4 pairs of two-boat purse seiners was 11,582 t (skipjack 33 per cent, yellowfin 54.8 per cent, others 12.2 per cent) and the average catch per pair was 2,859.6 t. At the end of February 1969, the pair of No. 52 Hakuryu-Maru vessels also turned back to Japan for overhauling hull and engines.

The present third stage

Due to departure of some boats, we were forced to have a major cutback in our fleet, but we are continuing seining operations. Although the main fisheries for tunas off West Africa had been conducted by pole and line and longline in the past, a recent tendency has been to change to purse seining and to enlarge the size of boats. In addition, with the increase in the number of American purse seiners, competition has become more intensified. But it appears that West Africa will develop into an international fishing ground for tuna purse seining.

FISHING SEASON AND FISHING AREA

Surface fishing areas for tunas along the West African Coast are vast. In this area, the Canary Current and the Guinea Current run from north-west to south-east in the north zone and the Benguela Current and the Equatorial Current run from south-east to north-west in the north zone. These two great ocean current systems form a current-rip north of the equator. Many schools of tunas migrate along this current-rip from south and north, making it the best seining area off West Africa.

However, we have not conducted fundamental scientific research in this area. Due to a lack of practical experience, we have not secured knowledge about distribution of all good fishing areas and good fishing seasons. Therefore, we suspect that there are still many unexploited areas for tuna fishing off West Africa.

With our experience in the past several years, we gained some information about fishing seasons and fishing areas as follows:

Fishing season

Generally speaking, the period between July and January is the best season for tuna purse seining, during which, according to the fishing statistics, 85 per cent of the

annual catch has been made. The fishing season depends on weather conditions. The rainy season beginning in April, reaches the zenith in May or June, and the temperature of the surface water is brought down to 21–22°C. This temperature change moves from east to west.

When the surface temperature falls below 22°C, density of schools becomes high and fishing is good. During the period August and September, the weather improves as rainfall decreases, and sea temperature begins to rise to 24–27°C. In this period, large schools of yellowfin appear on the surface southward of Sao Tome Island.

After that, surfacing schools are observed off the coastline fron Tema to Abidjan in October. Another good seining area is off Cape Three Points in November/December. After mid-December, the temperature of sea water rises to 28°C and higher, and many small surfacing schools can be observed.

After the end of January, water temperature continues to rise. Sometimes it reaches 30°C. In this period, many small surfacing schools are observed. Since the motion of these schools is very quick, it is difficult to catch them with purse seines.

Fishing areas

The whole coast of West Africa is a fishing area, but we have divided it into three main fishing areas, namely (a) Eastern, (b) Central and (c) Northern, according to our data of tuna distribution.

(a) The Eastern fishing area—This area extends from Principe Island southward to Point-Noire and westward off Annobon Island over the continental shelf. It is 500 mi long and 300 mi wide. Main fishing areas are the south of Sao Tome Island and east of Annobon Island (0°–2°S, 5°–8°E).

Yellowfin schools of several hundred tons have often been observed on a current rip in these areas, but once they submerged, we could not find them. This is a common occurrence there.

Large schools of skipjack, yellowfin and frigate mackerel are found off the mouth of the Congo River at the beginning of July and around 02° 30'S in August and September.

(b) The Central fishing area—This area reaches about 500 mi from off Tema to Abidjan, centring around Cape Three Points (5°N, 1° 30'W), over the continental shelf. It has been fished by our pole and line boats since 1962 and has an abundant resource of sardines for bait. Thus, many schools of skipjack and yellowfin are available. The water depth is about 200 m, and there are also some mixed schools consisting of skipjack, yellowfin, frigate mackerel and other fish throughout the whole year.

During the period September–December, the water temperature is 24–27°C and the best seining season occurs due to the schooling behaviour of the fish.

Recently, a new fishing area for yellowfin was found on a current rip 100 mi off the coastline during November and December. We expect future exploitation in this area. During the rainy season May to July, the current speed from west to east is 2.5 kn maximum, and we often experienced difficulty in setting the gear.

(c) The Northern fishing area—This area reaches 200 mi from off Monrovia (06° 30'N, 10° 30'W) to off Freetown (08° 30'N, 13° 00'W), water depth is about 200 m over the continental shelf. There is a good seining area around 7°N, but it has unstable weather and poor sea conditions. Under these circumstances, fishing operations are decreasing gradually.

During the period October–November, some skipjack schools frequently appear at the 200 m depth line. The best seining season in this area is between April and June, and large yellowfin schools surface around 7°N, but they often disappear due to a change in the weather. Furthermore, there is often a sudden change of current direction in this area, and we have experienced some troubles such as broken nets. As the fishing area off Freetown has an abundant resource of sardines, tuna schools consisting of skipjack and yellowfin have been observed.

During June and July, rainfall reaches the maximum and muddy streams from rivers make it difficult to find schools of skipjack and yellowfin and sardines; due to this, the importance of this area will decline in future.

TABLE 1. SPECIFICATION OF VESSELS

	Main boat	*Sub boat*	*Attendant boats*	
	No. 81 Kuroshio-Maru	No. 82 Kuroshio-Maru	No. 51 Kuroshio-Maru	No. 52 Kuroshio-Maru
Gross Tonnage	145.54	145.28	99.17	99.26
L × B × D m	28.00 m × 6.40 m × 3.00 m	28.58 m × 6.40 m × 3.00 m	27.00 m × 5.00 m × 2.50 m	27.00 m × 5.50 m × 2.50 m
Fish hold m^3	78.69/20	,,	42.54/15	44.19/15
Fuel Tank	33.52	,,	46.16	,,
Main Engine	MA6S 550 hp	,,	MA6SS 620 hp	MASS 620 hp
Auxiliary Engine	6MLT 300 hp	,,	K5BM 100 hp	K5BM 100 hp
Radar	J.M.C. 123 C	—	—	—
Direction Finder	KS-347 A	—	—	—
Fish Finder	Sonar, type NTB 11 1,500 A	—	Vertical Type TL-32	K5BM 100 hp
Purse Winch pull/speed	9 ton/24m/min 4.5 ton/36m/min	,,	—	—
Side Winch pull/speed	4.2 ton/48m/min	,,	—	—
Net Hauler pull/speed	3.5 ton/20m/min	,,	—	—

FISHING OPERATION

Purse seiners in West Africa are of the one-boat type equipped with power blocks. Our two-boat purse seiners are the exception. There are advantages and disadvantages in both systems, but we wish to determine which is superior. The following is an example of two-boat purse seining by the two-boat purse seine unit of No. 81 Kuroshio-Maru which consists of four vessels specified in Table 1.

Fish finding

Usually, searching for fish begins about half an hour before sunrise. The four boats make an effort to find a sign of birds, floating objects, whales, porpoise or white splashes made by feeding fish.

A unit of operation is formed with the main boat in the centre, arranging the sub boat to leftside, keeping a distance apart of 2,000–3,000 m and by arranging the attendant boats to the leftside and rightside, keeping a distance 2,000–3,000 m from both the main boat and the sub boat. Under the command of the captain, each boat stations several watchmen, and continues to sail in contact by radio covering a wide area. When a sign of fish is found, the attendant boats approach the school and report to the main boat the size and behaviour of the school.

Setting the net

When the school is sighted, preparations are made to set the fishing gear. The main boat and sub boat join the net at the bunt part, connecting each other with the net and the painter and proceed to the school.

The two attendant boats approach the school as near as possible (fig 1) and report the kind of fish, behaviour of the school (by using the fish finder) and in addition, current speed and direction. The seine boats advance to the school, and at a distance of about 1,000 m prepare to set the net to intercept the school. Occasionally, this operation is done from the right, left or rear side in cases of strong current (over 0.5 kn), crossing the direction of the current and the school or in the same direction of the current and the school. The main purpose of this is to assure good performance of the main body of the net by drifting the bunt under the influence of the current after completion of the set. An ideal setting operation should be started at a point 700 m in front of the school, and should be completed when the school is at a point $\frac{1}{3}$ of the distance from the finishing point of the set.

There are two methods used in setting. One is when the two vessels proceed in a straight line for a short distance before starting to separate. This is done to make the bunt sink fast. The other is the case when the boats start shooting the bunt steering in opposite directions. In this case, sinking of the bunt will be delayed by the pulling power of the boats. The former is named V shaped setting and the latter as U shaped setting.

Setting is started by letting-go the painter between the main boat and the sub boat. Then the net is slipped into the water by the moving force of the boats. It is desirable that the setting speed be maximum to surround the school as quickly as possible, but the sinking velocity of the net might be reduced by excessive force exerted by the boats. Therefore, care should be taken to make the net sink fast by choosing the correct setting speed.

Generally, the shape of the net must be round to surround the school perfectly, but the sinking performance of the net after completion of pursing is better when the shape is an ellipse rather than circle. During setting, the attendant boats circle outside of the school to drive it into the net, and they guide the main boat and the sub boat to surround the school perfectly. Also, during pursing, they repeat small back and forth manoeuvres to prevent the escape of fish from the open section between the ends of the seine.

Hauling the net

After completion of the set, main boat and sub boat tie painters at bow and stern to each other and pay out

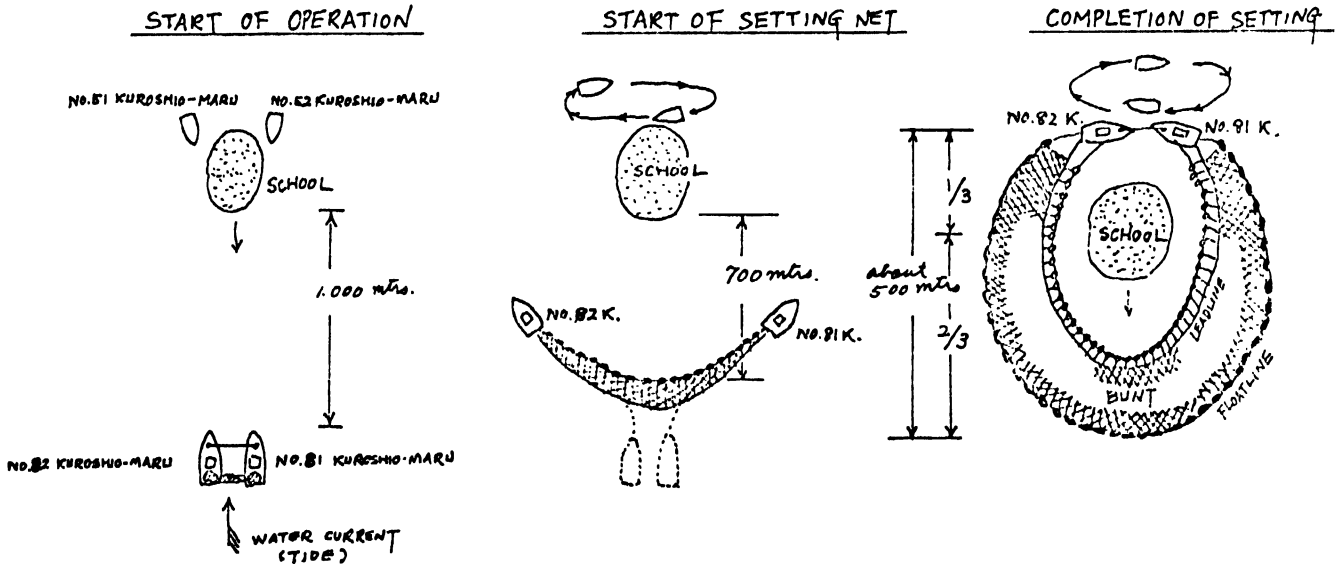

Fig 1. Setting operation

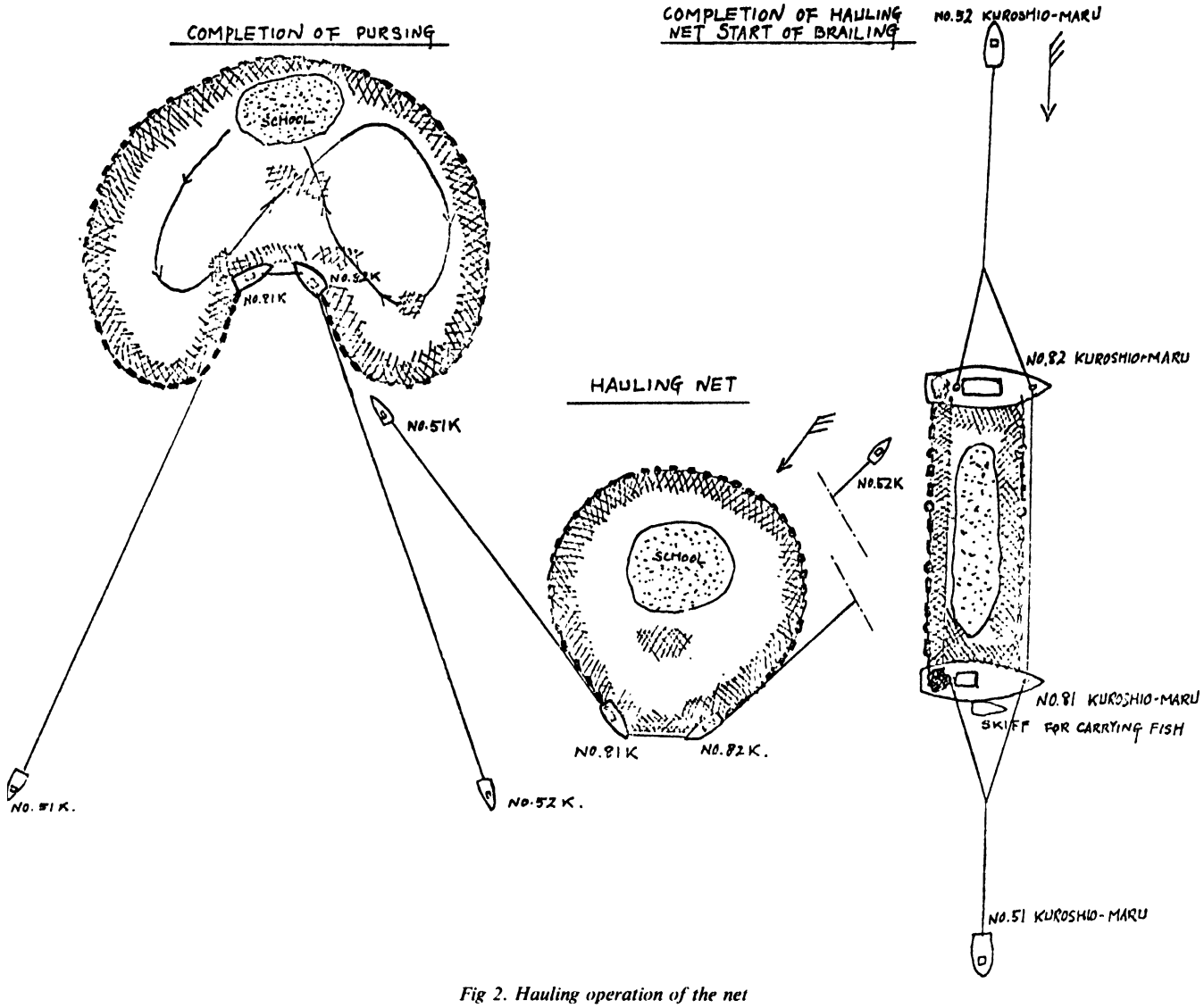

Fig 2. Hauling operation of the net

an excess of from 20 to 50 m of purseline to ensure good performance of the leadline. After this, they begin to haul the purseline by winches. Time required for pursing is 40 to 60 min, depending on the current.

As soon as pursing is completed, hauling starts by using net haulers installed on the stern. The hauled net is stacked in the netbin in good order ready for next set. During hauling, the attendant boats tow main boat and sub boat with towlines as instructed by the captain or sub-captain to make the hauling easy (fig 2).

As floatline and net often drift under influence of current and wind, additional skiffs also pull the floatline.

Brailing

If the catch of fish is estimated at less than 20 t it may be brailed from the bunt directly. But, if it is in excess of 30 t a blanket net of strong netting is joined to the side of the bunt and replaces the bunt which would not be strong enough. Brailing is then begun by using a brailing net (figs 3 and 4).

When the triangular brailing net is set into the blanket net (which is spread between main boat and sub boat), the front of the brailing net is taken by the main boat and the end by the sub boat. An iron ring attached on the end of the triangular net is joined with a shackle to a wire rope suspended between main boat and sub boat. The ends of bridles attached to the front of the net are connected to winches on the portside gunwale of the main boat. The sub boat draws this net towards itself by hauling the wire rope. The leadline of the net is extended fully to the right and left on the starboard side of the sub boat. The net is then submerged to the bottom of the blanket net and the bridles attached to the leadline are pulled toward the main boat. If the net is set deep enough, it is easy to scoop the fish which flow into the pocket at the end of the net. The net is then hauled over the gunwale and the fish in the pocket flow on to the deck of the main boat and are then tranferred to the carrying skiffs on the starboard side of the main boat which bring it to the freezer mothership.

This brailing net has a capacity of 20 t per hour in normal conditions and 35 t at maximum. During brailing, the fish may suffocate and die in the blanket net due to blood from their fellows. To prevent this, the attendant

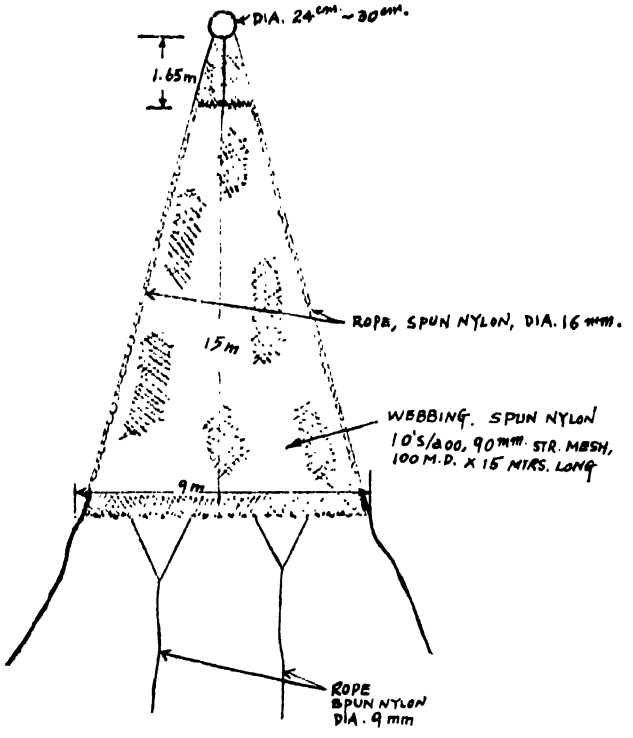

Fig 3. Brailing net

boats must tow main boat and sub boat against the current.

FISHING GEAR

Fishing gear of our two-boat tuna purse seine operations off West Africa was fundamentally the same as those used in the North West Pacific off Japan, but we made special improvements in constructing the net for the conditions of the fishing grounds. However, there are still considerable problems, so it is desirable to improve them further.

Net No. 1 at the start of the tuna purse seining operation (1964) off West Africa is specified in figs 5 and 6 and Tables 2 to 4.

As observed in model tests, considerable changes in the hanging ratio along floatline and leadline due to unequal shrinking and lengthening of lines and netting affected the sinking performance more and more. Consequently, catching efficiency decreased, because fish frequently escaped during pursing. After 92 sets, the net was re-measured in detail and it was found that the tar-treated netting had shrunk by about 5 per cent. On the other hand, the floatline had been stretched by about 25 per cent. This clearly indicates that during fishing operations the net gradually gets out of balance which explains the gradual decline in fishing efficiency.

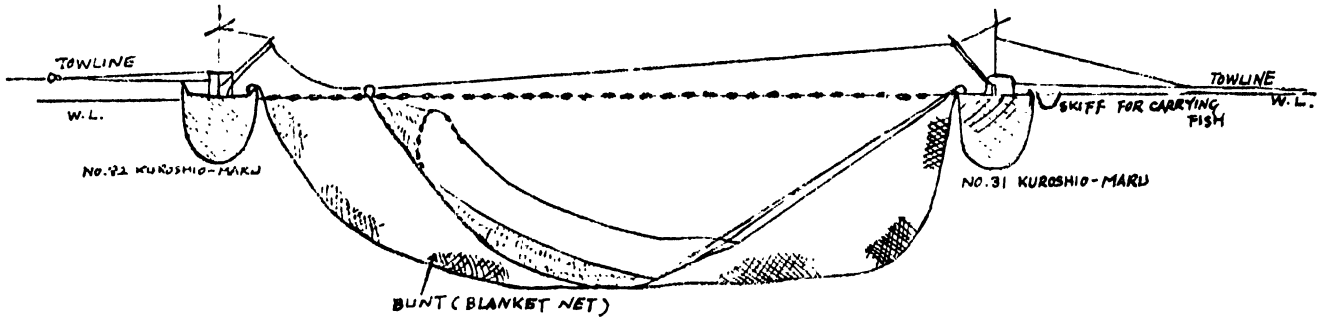

Fig 4. Brailing operation with the brailing net

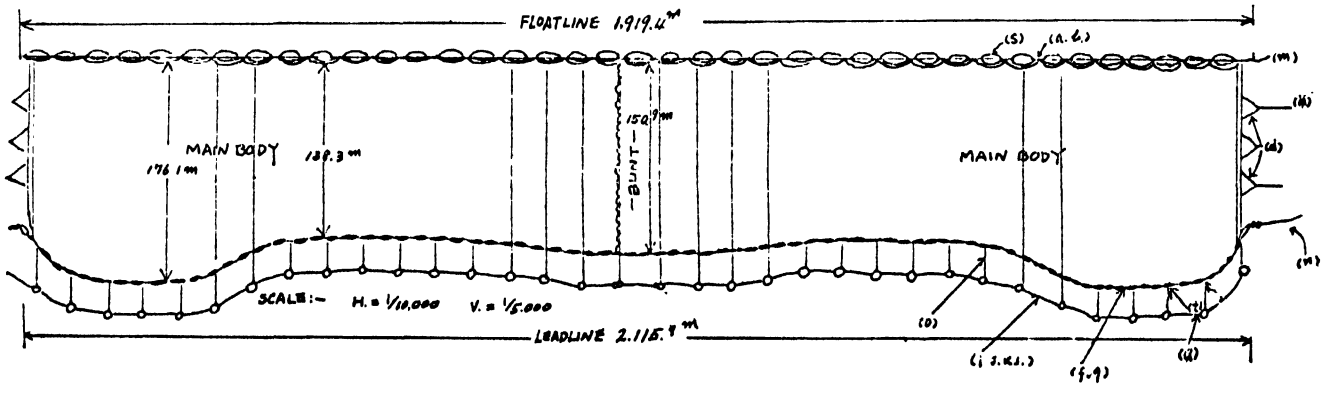

Fig 5. Diagram of tuna purse seine No. 1 at the start of fishing operations (1964)

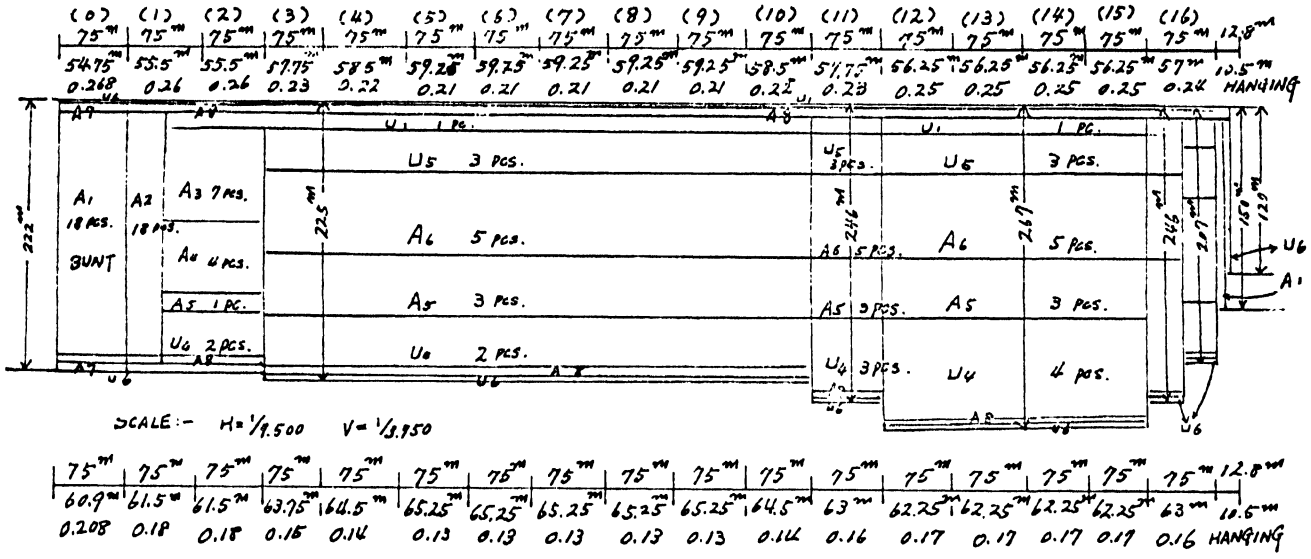

Fig 6. Specification of netting of tuna purse seine No. 1 (right half plus bunt)

Purse seine No. 1 was used for 348 sets between November 1964 through December 1965. During this period the construction was modified by replacing netting and changing floatline lengths. Nevertheless, results were unsatisfactory, i.e. the fishing efficiency could not be sufficiently improved and there were also serious problems with net damage, which started after the net was put into use and vital parts had been repaired or modified.

After 18 months experience in tuna purse seining off West Africa, the following modifications of the net were introduced in July 1966:

Length of floatline = 2,325 m
Stretched length of netting = 3,360 m
Stretched depth of bunt = 288.3 m (190.5 m hung)
Stretched depth of main body = 345 m (214.5 m hung)
Stretched mesh size of netting = 105–360 mm.

The size of the net was increased to better counteract the escape of fish. The mesh size was increased to reduce resistance of the net in water currents. These two main modifications still did not lead to fully satisfactory results. Although the net had less current resistance it broke easily because of its large size. Consequently, the size of the net was reduced again by about 7 per cent and also part of the netting was made of stronger twine, i.e. nylon 210d/30 was replaced by 210d/36 and 210d/36 was replaced by 210d/45. This modification proved satisfactory

TABLE 2. MATERIALS OF NET NO. 1 EXCEPT NETTING

		ømm	
(a) Floatline	PP	18 (S)	10 coils
(b) Bolshline for floatline	PP	22 (Z)	8 ,,
(c) Bolshline for floatline	PP	24 (Z)	2 ,,
(d) Guy Rope	SN	16 (S)	2 ,,
(e) Guy Rope	SN	16 (Z)	2 ,,
(f) Leadline	SN	16 (S)	11 ,,
(g) Bolshline for leadline	SN	16 (Z)	11 ,,
(h) Breastline	SN	18 (Z)	10 ,,
(i) Purseline	WR	16	6 ,,
(j) ,,	WR	18	4 ,,
(k) ,,	WR	20	2 ,,
(l) ,,	WR	22	4 ,,
(m) Towline for floatline	WR	12	2 ,,
(n) Towline for leadline	WR	12	2 ,,
(o) Ring bridle	V	18	7 ,,
(p) Connecting rope	SN	9	4 ,,
(q) Poachline	FN	9	11 ,,
(r) Staple	SN	10's/30×3×3	7 ,,
(s) Float	Vinycon G-7		4,737 pieces
(t) Lead	375 g		7,760 ,,
(u) Ring	Steel	180	200 ,,
(v) ,,	Steel	210	2 ,,
(w) Swivel	Steel, Large Type		2 ,,
(x) ,,	Steel, Small Type		4 ,,

1 coil = 200 m
PP = polypropylene
SN = spun nylon
WR = wire rope
V = vinylon

TABLE 3. SPECIFICATION OF NETTING FOR PURSE SEINE NO. 1

Netting Section	*Material*	*Twine No.*	*Mesh size str. mm*	*Depth meshes*	*Length m*
A-1	Nylon	210d/60	120	100	1,650
A-2	,,	210d/48	,,	,,	1,350
A-3	,,	210d/36	,,	,,	2,625
A-4	,,	,,	150	,,	1,500
A-5	,,	,,	180	,,	6,000
A-6	,,	210d/30	150	,,	9,375
A-7	,,	210d/75	120	20	150
A-8	,,	210d/60	,,	,,	4,830
A-9	,,	,,	,,	10	1,950
U-1	Spun Nylon	20's/36	,,	100	2,400
U-2	,,	,,	150	,,	220
U-3	,,	,,	180	,,	375
U-4	,,	,,	210	,,	6,075
U-5	,,	20's/30	120	,,	5,625
U-6	,,	20's/150	150	,,	5,220

TABLE 4. BALANCE OF SINKING FORCE AND BUOYANCY OF THE MATERIAL OF NET NO. 1

Name of section	*Material*	*Quantity*	*Weight*	*Density j/cm³*	*Weight in air Kg*	*Sinking Force Kgf*	*Buoyancy Kgf*
Webbing	Nylon	6,200 Kgs		1.14	6,200	763	—
	Spun Nylon	4,800 Kgs		1.14	4,800	590	—
	Treated tar on webbing			1.10	3,970	362	—
Mounting Twine	Nylon	120 Kgs		1.14	120	15	—
	Spun Nylon	258 Kgs		1.14	258	32	—
	Treated tar on twine			1.10	260	24	—
	Polypropylene		*kg coil*				
Floatline	Dia 18 mm	10 coils	30.5	0.91	305		30
	Dia 22 mm	8 coils	40.0	0.91	320		36
	Dia 24 mm	2 coils	53.0	0.91	106		11
	Nylon						
Staple	Dia 9 mm	11 coils	11.0	1.14	121	16	
	Spun Nylon						
Leadline	Dia 16 mm	26 coils	31.0	1.14	806	99	
	Spun Nylon						
Guy rope	Dia 16 mm	4 coils	31.0	1.14	124	11	
	Wire Rope		*kg/m*				
Purseline	Dia 16 mm	6 coils	0.85	3.10	1,020	691	
	Dia 18 mm	4 coils	1.08	2.80	864	556	
	Dia 20 mm	2 coils	1.33	2.50	532	319	
	Dia 22 mm	4 coils	1.61	2.40	1,288	751	
	Vinylon Rope		*kg/coil*				
Ring Sling	Dia 18 mm	7 coils	43.0	1.30	301	70	
	Spun Nylon						
Connecting Rope	Dia 9 mm	4 coils	27.0	1.14	108	13	
	Spun Nylon						
Poachline	10'S/30×3×3	7 coils	4.6	1.14	332	4	
Lead		7.760 pieces	375 g each	11.35	2,910	2,654	
Ring, Steel	Dia 180 mm	200 pieces	1.0 kg each	7.80	200	174	
Swivel, Steel		6 pieces	5.0 kg	7.80	30	26	
Float, Vinycon G-7		4,737 pieces	351 g each		1,663		14,211
				Total ..	26,214 Kg	7,159 Kgf	14,288
			Balance of Sinking Force and Buoyancy (Surplus Buoyancy) ..		7,129 Kgf		

in the beginning, but after about 100 sets, the problem of breakage started again, indicating that construction still needed to be improved.

CONCLUSIONS

According to experience so far, there are good tuna purse seining opportunities along the West African Coast, and the Japanese two-boat purse seine technique is basically suitable. The net construction reached so far, however, is still not satisfactory and also more experience is needed with regard to the inter-relation between fishing gear, fish behaviour and general fishing conditions in this area. It is expected these problems can be solved within the near future.

The Japanese purse seine operations for West Africa are centred around the freezer mothership. This system is unique and its success depends on the relation between catches and refrigeration capacity of the mothership, which still present some problems which need further investigation and rationalization.

The Icelandic Technique of Sonar Guided Purse Seining

Thorsteinn Gislason

Technique islandaise de pêche à la seine coulissante guidee par sonar

Jusqu'à la fin de la deuxième guerre mondiale, les Islandais utilisèrent des seines en coton à deux bateaux virées à la main, les bancs de hareng étant localisés visuellement du bateau ou par prospection aérienne. Après 1944 le comportement du hareng se modifia; le poisson demeura au large en eau profonde et ne fit plus surface que rarement. C'est alors qu'on a commencé à utiliser les seines avec la poche à une extrémité. Le sonar, utilisé pour la première fois en 1954 pour l'encerclement des bancs nageant en profondeur, est devenu rapidement un équipement standard sur tous les seineurs islandais. L'emploi des filets en nylon et des flotteurs en plastique a débuté vers 1957. Le Puretic power block a été introduit en 1959. Dans l'espace de deux ans, le système à deux bateaux est complètement abandonné et la pêche à la seine coulissante guidée par sonar devient une activité pratiquée à longueur d'année, non seulement pour le hareng mais aussi pour le capelan, la morue et le lieu noir. Les dimensions des seines se sont accrues de 290×55 m (160×30 fm) à 580×220 m (320×120 fm), avec iusqu'à 8,8 kg de plomb par mètre (16 kg/fm). Les navires ont augmenté de taille jusqu'à une moyenne de 38–41 m (125–135 ft); ls sont équipés de treuils de coulisse de 12 à 20 t de traction et de pompes à poisson, ainsi que souvent de propulseurs transversaux. On n'utilise pas de skiffs d'assistance ou de "bas-boats", mais on emporte seulement des annexes en plastique stratifié à moteur hors-bord ou des radeaux pneumatiques en cas d'urgence. Face au vent ou vent arrière, des coups de seines peuvent être faits par vent de force 6 à 8. On discute de rôle du patron de pêche dans le projet et la conduite dy voyage de pêche. la recherche du poisson et l'estimation des bancs à l'aide du sonar, ainsi que du perfectionnement du patron au moyen de la pêche simulée.

Tecnica islandesa de pesca con red de cerco orientada con sonar

Hasta después de la Segunda Guerra Mundial, los islandeses usaban redes de cerco de algodón, maniobradas desde dos barcos con pareja, que se halaban a mano y los cardúmenes de arenques se localizaban visualmente desde el barco y mediante exploración aérea. Después de 1944 cambió el comportamiento de los arenques, los peces permanecían en aguas profundas y raras veces salían a la superficie. Entonces empezaron a utilizarse redes de cerco con el copo en un extremo. El sonar se empleó por primera en 1954 para descubrir los cardúmenes que nadaban en aguas profundas, convirtiéndose pronto en el equipo normal de todos los barcos islandeses que pescan con redes de cerco. Las redes de nilón y los flotadores de plástico empezaron a usarse alrededor de 1957. La polea "Puretic" para el listado mécanico del arte se introdujo en 1959. En dos años desapareció completamente el sistema de pesca con parejas y la pesca con redes de cerco orientada mediante sonar se convirtió en una pesquería que se efectuaba durante todo el año, no sólo para pescar arenque sino también capelán, bacalao y colín. El tamaño de las redes de cerco aumentó desde 160×30 brazas a 320×120 brazas llevando hasta 16 kg de plomo/braza. El tamaño de las embarcaciones aumentó a 125–135 pies, por término medio, con maquinillas par la red de 12 a 20 toneladas de fuerza de tracción, bombas para aspirar los peces, y dotadas a menudo con hélices aproa de empuje transversal. No so usan botes auxiliares sino pequeños botes de fibra de vidrio con motores fuera de bordo o lanchas de goma para casos de emergencia. Ofreciendo la proa o la popa al viento, se pueden efectuar lances con un viento de fuerza 6 a 8 de la escala Beaufort. Se examina la función desempeñada por el patrón en la preparación y dirección del viaje de pesca, la busqueda de los peces y la evaluación de los cardúmenes por medio del sonar, así como la capacitación del patrón para la pesca simulada.

SINCE herring purse seining started in Iceland in 1904, no other single factor has caused such profound or serious fluctuations in the life of the nation. This is the biggest lottery. During the first four decades after purse seining was introduced, the fishery was limited to a summer season, mostly inshore in bays and fjords when the herring came to the coast in June or July on a feeding migration. The herring was caught when it was fat and a good raw material.

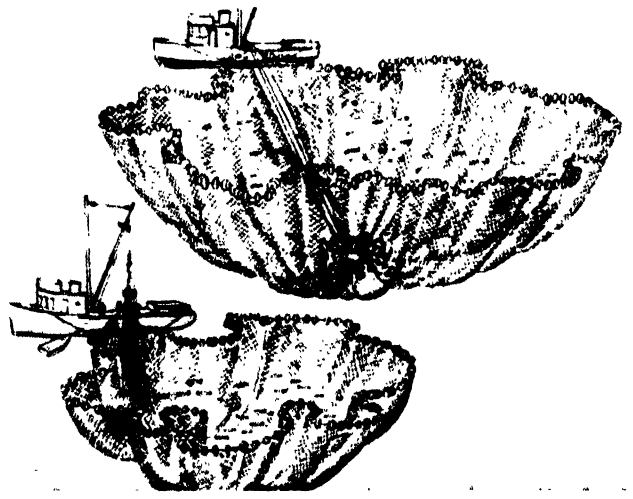

Fig 1. The U.S. Pacific coast one-boat method demonstrated in Iceland by M.S. Fanney

The two-boat method was used, modelled on the U.S. menhaden net and mode of operation. The two 30 ft net boats were rowed, the net was set and pursed manually and the fishing power depended very much on the strength of the crews. The seines were of cotton, 120 to 180 fm long and 20 to 35 fm deep. The purseline was of hemp. The bunt was in the centre of the net. Only some fishing vessels could carry the net boats in davits. The smaller vessels had to tow them.

After 1936 began mechanization of the net boats, which were, in due time, also fitted with mechanically-driven warping heads for pursing. During World War II,

Fig 2. One-boat purse seining using a 32-36 ft net boat

some minor modifications began to be made in the design of the nets and arrangements on board the fishing vessels.

However, it was not until 1945 that further progress was made after the introduction of a U.S. Pacific Coast type purse seiner M.S. *Fanney*. She was built in Takoma, U.S.A., as a demonstration boat for Government organizations at the suggestion of Hilmar Kristjonsson who had become familiar with vessels of this type in California and Alaska with labour-saving arrangements which made possible the operation of the same size net and vessel with half the crew then used on Icelandic vessels. The U.S. method of strapping in the net with the help of a high boom (fig 1) did not suit Icelandic boats with wheelhouse aft, but the nets, especially on smaller boats, were gradually changed for one-boat purse seining with the bunt in one end and the seine was carried in one net boat, 32 to 36 ft, which was towed by the main fishing vessel (fig 2). During setting and pursing, the net boat was towed at the side of the main boat which pursed on its winch while the net was dried up by hand into the net boat (fig 3). The gain was:

1. Fifty per cent smaller crew because the net was hauled from one end only
2. More speed when approaching and setting around a school in competition with other boats
3. Faster pursing with a powerful winch
4. It was easier to tow one boat than two in adverse weather
5. Time saved for manning the net boats when approaching schools and manoeuvring up to the net boats and net for brailing.

Fig 3. The net hauled by hand from one end into the net boat

It seems safe to say that the theories of Dr. Arni Fridriksson concerning the life history and migration pattern of the Norwegian-Icelandic herring stock spawning off the coast of Norway and feeding near Iceland, have been the basis for later investigations. This is the biggest of the three herring stocks on which the Icelandic herring fishery is based. Normally it was relatively easy to find the herring schools in the surface waters and in Iceland aerial scouting was a regular feature from 1928 until 1955, most of the time with two planes. After 1944, the migration pattern and behaviour of the Norwegian-Icelandic herring changed drastically. Although the stock on which the fishery was based was probably not smaller than before, no herring came to the traditional inshore

Fig 4. The herring searching and research vessel R.V. Arni Fridriksson *which traces the herring and capelin migrations, directs fleet searching and leads the ships to fish concentrations (see J. Jakobsson, p.2 ff)*

grounds at the Icelandic coast. As the herring stayed further out in deeper water, mainly off the east coast, the schools surfaced seldom and irregularly, and consequently a new technique was needed.

Sonar introduced

During the last World War, sonar was developed and used for detecting submarines. After the War, Norwegian sonar and fisheries research experts started experimenting with sonar for herring detection. Conclusive results were obtained in 1950, but in Iceland the first sonar was installed in 1953 in the Patrol and Research Vessel *Aegir*, with which the fisheries biologists, Dr. Hermann Einarsson and Mr. Jakob Jakobsson, obtained excellent results in herring searching and study of the annual migrations at Iceland and in the Norwegian Sea (fig 4). However, it was not sufficient to detect herring which did not school on the surface. A technique had to be evolved for catching it.

In 1954, small manually-operated sonar units were first installed in four Icelandic fishing vessels. Already, during the first summer season, very positive results were obtained, especially on board the M.S. *Vidir* under the command of Skipper Eggert Gislason (fig 5), who in

Fig 5. Skipper Eggert Gislason, pioneer of sonar-guided purse seining, studies an impressive sonargram

subsequent years was a leader in the development and application of sonar-guided purse seining, which in the next years was adopted by all Icelandic herring skippers. That the Icelandic fishermen were so quick to utilize the sonar, not only for finding the fish but also for guiding the setting of the seine, can be attributed to the following factors:

(i) During the summer of 1954 and subsequent years, herring schools in the surface were scarce.
(ii) The hydrographic sonar conditions are particularly good off the Northeast coast of Iceland, especially north of 65°N, and far better than off the Norwegian coast or in the North Sea, where the same type of sonar units had been tried with inconclusive results.
(iii) The net was set from a boat towed at the side of the main vessel which could therefore be manoeuvred on the basis of information from the sonar.
(iv) The skippers cooperated exceptionally well, teaching each other and exchanging information immediately they found herring.

Perhaps one incident was also of crucial importance. In 1954, Eggert Gislason found a submerged herring school and attempted setting the net around it with the help of his hand-trained sonar. The fish escaped and, while the net was being hauled in empty, Skipper Gislason followed the school's progress outside his net on the sonar. He then called a nearby vessel without sonar and over the R.T. he directed the skipper in setting his net perfectly around the school. The entire Icelandic purse seining fleet was in the neighbourhood and everybody followed keenly the radio conversation between the two skippers. When the second boat filled up from this single set, this was a dramatic proof which undoubtedly encouraged skippers and owners to fit sonar units.

In subsequent years, the herring stayed even further away from Iceland and the situation became increasingly difficult, especially with smaller vessels. In 1959 a Puretic power block was fitted on M.S. *Gudmundur Thordarson* and, I believe, this was the first vessel with wheelhouse aft on which the power block was successfully used. To get rid of the net boats (dories) made a tremendous difference. The hard work of hauling the net manually disappeared because now the net came slack down to the deck from the power block overhead, and was flaked easily underfoot on the boatdeck aft of the wheelhouse and steamed out from this place during setting. During the next two years, the two-boat system disappeared completely in Iceland.

After the introduction of the power block, purse seining became a year-round fishery, not only for herring but now also for capelin, cod and coalfish (fig 6). However, it became obvious that cotton seines were no longer adequate. Nets of nylon and other synthetics came into use in Iceland about 1957 and the advantages were soon

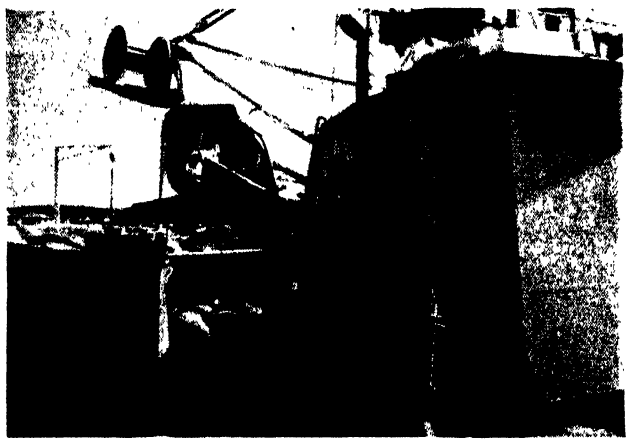

Fig 6. The big and heavily weighted seines forced the development of very powerful net haulers and these were mounted low and forward on the boatdeck with separate stacking blocks over the net bin

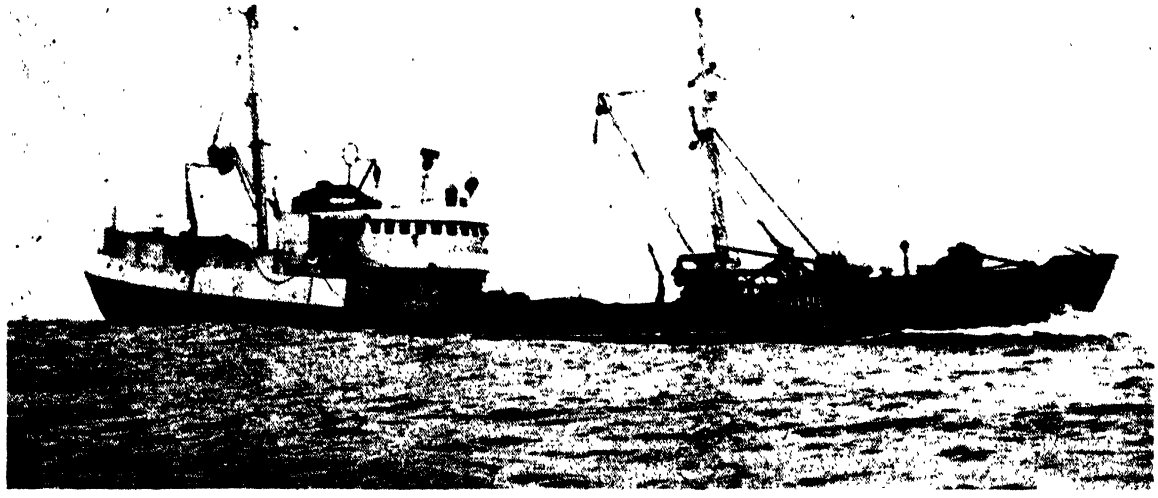

Fig 7. With the advent of bigger seines, winches and hauling devices, more powerful and larger ships were fitted out for purse seining, including side trawlers of 150 to 200 ft

obvious—light, strong and durable. Another great advantage was to have plastic foam floats instead of cork.

In those days, the seines were about 50 fm deep maximum and 160 fm long, with 3 kg of lead on each fathom of the sinkerline—total weight of net about 3 t. With the advent of winter herring fishing, the development was towards fetching the herring ever deeper and deeper. Today, seiners are up to 130 fm deep and 320 fm long with up to 16 kg of lead per fm and made of heavy nylon twine so that the nets weigh up to 12 t. Consequently, it became necessary to use bigger and more powerful power blocks and also add stacking blocks (fig 7).

Early sonar units did not have tiltable transducers and it was soon felt that they did not look steeply enough down for guiding the setting operation for deep swimming schools. Some Icelandic fishermen then had a second transducer mounted at a 30° angle below the original one and switched on either one as needed. This soon became standard equipment from the manufacturers and subsequently the tiltable transducer and other refinements were incorporated.

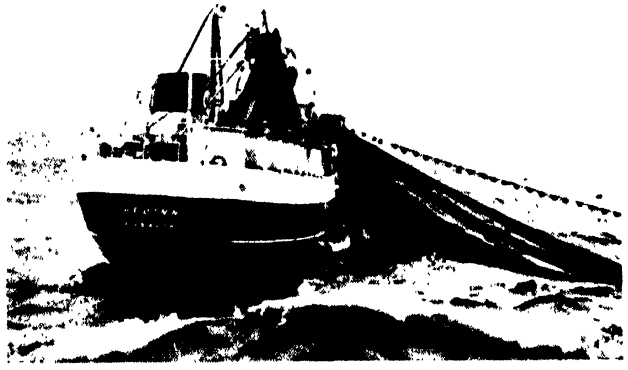

Fig 8. Hauling the net with a pedestal-mounted power block and stacking block aboard a vessel fitted with transverse thrusters, stern facing into the wind

The purse seiners became bigger, whereas during the first years after the power block, it was considered unhandy to use ships of more than 100 ft. Today, boats of 200 ft are fitted for purse seining (fig 7). Transverse thrusters and active rudder have been fitted in many ships and this has facilitated the fishing, although not strictly necessary (fig 8).

Fish pumps were introduced and under certain circumstances they made it possible to increase the rate of transfer of fish from the net to boat up to 400 tons per hour from 250 tons per hour with ordinary brailing (fig 9). The pumps are particularly effective for loading capelin (fig 10). However, some types of pumps cut and descale the fish. In 1960, the ships normally had purse winches with 4 t pull. By 1970, the bare drum power had risen to 20 t.

Fig 9. Maximum drying-up of the fish in the net speeds up brailing, but causes the fish to die sooner and sink

During the years 1960–64, groups of foreign skippers, owners and research people came to Iceland to study the new purse seining technique and some features of it have found application elsewhere.

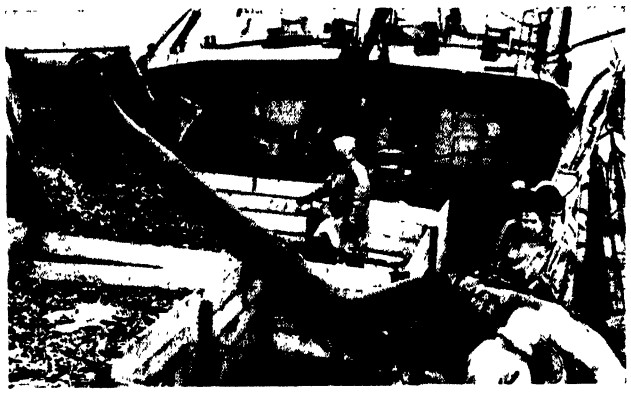

Fig 10. Capelin pumped from the net. The same equipment is used for landing the fish but the seawater separator seen on the left is then hoisted on to the jetty

PLANNING A FISHING TRIP

Each skipper must know the characteristics and the state of his ship from keel to mast top. He must remember that everything is his concern. When preparing a trip he must check with each crew member the condition and supply of those items for which they are responsible. While the engineer is responsible for the machinery, the skipper must check fuel oil supply and inform the engineer how long the trip might be. He must be familiar with the condition of the various machinery and instruments and ascertain that repairs have been made if necessary. Also he should check with the engineer that a sufficient supply of spare parts is carried for such repairs as can be made at sea.

Mates are in charge of work on deck. They must check that sufficient stores of drinking water are carried and that tanks are full if trips of some distance are ahead. They must also check that sufficient stocks are carried of spares for repairing and renewing the fishing gear, and adequate tools for the work on board. All this the skipper must oversee and check with his mates.

The cook takes care of provisioning but the skipper must indicate to him how long a trip might be. The skipper must check his navigational and radio communication instruments and maintain a supply of spare parts. The sonar units he must test and check spares and recorder paper. If the ship has been in slip he must check himself the transducers of the sonar and echo units. Echo sounder transducers often become loose because of electrolytic corrosion of fastening bolts which may need replacement. He must check that the sonar transducer is firmly in place and correctly orientated with respect to the direction indicator on the receiver unit. Finally, he must clean grease and growth attached to the sonar and sounder transducer surfaces but avoid doing so with rough tools. Either a fine sandpaper or steelwool should be used. At the same time, the skipper should check the keel and bottom of the vessel for protrusions on which the net might snag. It is the skipper's duty to do this himself.

Where to go?

This is one of the most important decisions of the fishing skipper who needs or can select his fishing area. Then it is of utmost importance that the information service be efficient both at sea and on land. Among the several things which must be considered are: all information concerning the fishing season as a whole; how the fishing goes and has been going; depth and bottom conditions considering the size and depth of the gear; weather forecast for the area under consideration; sea temperature; currents and moon phase. The fish in the various fishing grounds is greatly, but differently, affected by the moon phases, i.e. spring tides or neap tides, moonlight or darkness.

The skipper needs also to know the presence and behaviour of the fish as far back in time as possible under the different conditions which can be met in the various fishing grounds. Here is where his diary entries from earlier years are useful. These are some of the factors which earn the keen observant skipper what sometimes is called his sixth sense, i.e. the intuitive knowledge as to where to fish.

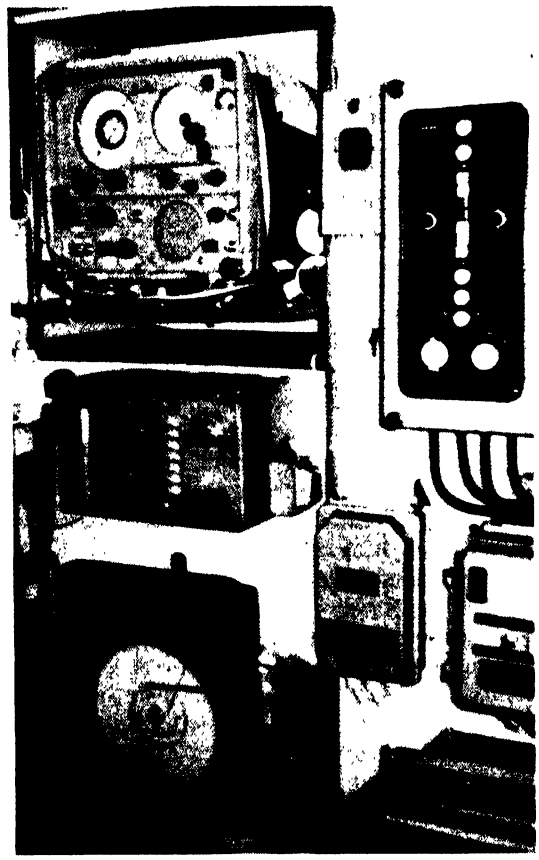

Fig 11. Indispensable aids to sonar-guided purse seining. From top to bottom: The automatic radio direction finder; the multi-channel radio; the thermograph—an effective aid in the search for fish

But beyond everything else, it is supremely important to watch out for all news from fishing and searching vessels after course has been set for the fishing grounds and be ready to change tack if warranted. Here is where the multi-channel R.T. is extremely useful since one can listen simultaneously on many wavelengths (fig 11).

FISH SEARCHING

Jakob Jakobsson's excellent description of fish searching and setting operation in purse seining in *Modern Fishing Gear of the World 2*, will not be repeated here but mentioned as a basic reference.

Fish searching with sonar is an exacting task where the skipper must apply the senses of both sight and hearing. Especially, he must train well his aural discrimination of sonar echoes. This can soon become easier and more exact than relying on vision which is distracted by so many other factors which concern the skipper commanding his ship while searching.

Not only are sonar units of various brands different, but also the same brand may function differently from one ship to another. The main reasons for this are the location and installation of the units (fig 12), as well as

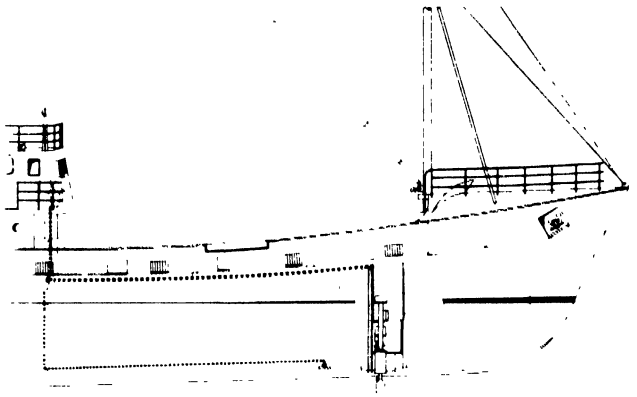

Fig 12. The correct location of sonar instruments is of prime importance. The transducer unit should, ideally, be about 7 m aft of the bow pp or at quarter point on the waterline length; the control/display unit should be at the front of the wheelhouse on the same side as that from which the net is worked

variations in shape and trim of the ships, and therefore, each skipper must know the characteristics of his sonar under various circumstances. In this connection, it is important to have as many as possible of the sonar adjustments inbuilt and pre-set by instrument specialists so that the skipper needs to tune the minimum number of knobs.

No skipper should omit testing how his sonar functions at the beginning of each fishing trip by aiming it at buoys, other ships, land, etc, and note whether the characteristics of the instrument have changed. Also he should note and remember well the sonar conditions in the various fishing areas and how they change seasonally. Confusing echoes can particularly be obtained in shallow water and over an uneven bottom. But one can quickly learn how to discern the scraping sound of echoes from bottom and bottom contours apart from the clinking echoes from fish schools which again differ according to species. Sonar has now become very useful in trawl fishing to locate the edges of rough bottom areas, rocks and wrecks.

When searching under good sonar conditions steaming in open sea, one should obviously use the maximum range of the sonar, say 2,500 to 3,000 m and at maximum power, searching over an arc of 130° to 140°. If depth is sufficient, as often is the case in the North Atlantic, it has been found most effective to incline the transducer 2° to 5° down from the horizontal, but in shallower water, as for instance in the North Sea where fish schools often are close to the bottom, it is better to search with the transducer inclined 5° to 10°.

When coming to a fishing ground where ships are crowding in a limited area, one should search at intermediate range, say 1,250 to 1,600 m. The unit then searches twice as fast and gives clearer information. When searching in very limited areas and in a dense fleet of vessels, as is often the case in winter fishing for herring and capelin, it is advisable to operate at 500 m range and incline the beam 10° to 15° to avoid echoes from other ships and their propeller wakes.

It is important for each skipper to know how to evaluate as exactly as possible the fish schools which are detected on the sonar and not to make a set on the first one if there is hope of another better. Then it is necessary to tune the units always consistently. When searching, one uses the greatest pulse length and strongest amplification up to the limit set by background noise, but when studying a school, one should always shorten the pulse length down to the minimum setting and reduce the power correspondingly, eventually from amplification 10 down to 5. By shortening the pulse length the echo becomes clearer and when the amplification is reduced the density of fish in the school can be seen more clearly. Then it often happens that the school which earlier seemed bigger and more desirable becomes now fainter and contains a smaller quantity of fish.

There is a reason to advise those skippers who change ships to study well the difference in location of the transducer units in relation to the tactics which they have been practising. One skipper may leave a short ship where the transducer unit has possibly been relatively far aft and take over a long ship with the transducer far forward, or vice versa. This calls for a very considerable difference in starting course and approach to a school during setting. It is, therefore, advisable for the skippers to work out on paper by drawing sketches, taking into account the length of the ship, distance and direction of the school.

It is no less important to approach schools slowly and quietly, especially if the fish are very active. One should avoid passing too close to a school, especially in calm sea, so as not to cause confusing echoes from the ship's wake and propeller wake of the ship. In the case of "nervous" fish one must take care before approach and setting operation commences to adjust the pitch setting of a controllable pitch propeller and also the engine speed at the same value as will be used during the setting operation. In this connection, it often seems that less disturbing noise is produced if the propeller is used at less than maximum pitch. It has also given good results when catching nervous (active) fish to start circling with a wide radius and reduce the circles before setting. Then it often seems that the fish become used to the noise from the ship and is less likely to dive. Schooling fish seldom remain stationary for any length of time. Therefore it is important that the one who directs fish searching should follow well the progress of fishing throughout the area and how the other ships behave, and also to follow well all the news on the radio telephone.

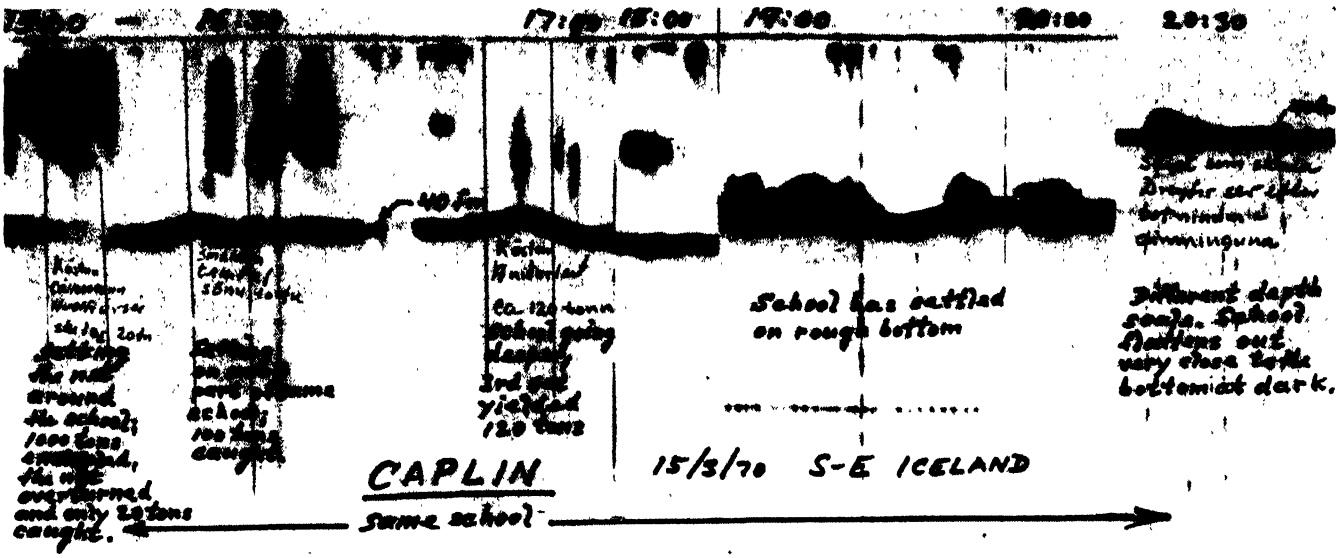

Fig 13. Sonargram (left) and a soundergram of a big capelin school. At 15 : 00 a set was made encircling 1000 t, but the net overturned and only 20 t were caught. At 16 : 30 another set was made on a small part of the same school and 100 t caught. At 17 : 00 at the onset of dusk, the school was going deeper but a third set yielded 120 t. At 19 : 00 the school had settled in dense clusters on the bottom and at darkness (20 : 30) the school spread out thinly on the bottom in 40 fm depth (different depth scale)

Often ships compete for a school and sometimes this leads to undue aggressiveness by the one which comes later. Then it has often proved effective to train the sonar beam at the newcomer and give full amplification and pulse length, thereby blocking out the utility of the competitor's sonar. The newcomer then usually leaves quickly—if he does not catch on to this trick in time.

Many factors come into play in fish searching and evaluation of schools and the tactics are perhaps as man as the skippers. But above everything else, the sonar technique requires patience. It is, therefore, the hallmark of a good sonar skipper never to give up because he knows that sooner or later he will succeed. An Icelandic proverb says that: "The sitting crow goes hungry, but the flying one gets food" (fig 13).

PREPARATION FOR MAKING A SET

Every detail concerning the preparation for fishing, the condition of the gear and ship is the concern of the skipper although he must select and delegate to the various crew members all tasks outside the wheelhouse. The skipper must keep an eagle eye at all times but preferably organizing things in such a way that the need for orders is kept to a minimum and that the crew functions like a well-oiled machine. This vastly improves the results and makes the work easier and more pleasant.

The work on deck is not complicated but in this type of fishing the ships often compete for schools. Therefore, fast reactions of the crew are extremely important.

The net must be so placed and arranged that it can run out without hinderance at a chosen moment. With the Icelandic method, no skiff is used but a buoy is attached with a suitably long tow rope to the bunt and end of the purseline. Part of the bunt is bunched and hung outside the ship's stern, suspended from a sliphook which must open easily. A sufficient amount of netting must be suspended to haul out the seine when dumped in the sea. The winch must run smoothly and the winch operator veering out the purse wire must have a good feeling for the correct amount of braking effect to be applied. Many mishaps in operating this sensitive fishing gear have been connected with the winch. Veering must be neither too fast nor too slow. Too slow veering drags down the buoy and can also semi-purse the net during setting. Veering too fast may cause the wire loops to slacken and foul on the drum, necessitating stopping setting and causing damage to the net. It is essential that the skipper be able to stop winch and power block from the wheelhouse. During setting, a single erroneous action can lose a big catch.

SAFETY RULES

The Code of Safety for Fishermen and Fishing Vessels—Part A, Safety and Health Practice for Skippers and Crews, published on behalf of FAO, ILO and IMCO (International Labour Organization, Geneva, 1970) contains the following 16 recommendations (pages 27 to 29) which should be kept well in mind by purse seining skippers and their crews:

1. To reduce the danger of fishermen stepping inside loops of purse ring bridles during setting of the net, the bridles should be coiled in the net or else stowed in a separate box or compartment next to the "clothespin" (rack or bar) from which the rings run out.
2. When setting begins, the net should be so arranged that it is pulled out by a buoy or skiff without the crew having to expose themselves to danger by going aft of or on top of the net.
3. During setting of the net the winchman should take care not to allow the drums to turn faster than purseline runs out, so as to avoid fouling the wire.

4. The extension rope attached to the tail end of the net should be coiled down in a separate box or compartment so that there is no danger of fishermen being caught in the loops during setting.

5. A sharp knife should always be kept handy near the net bin or platform

6. Fishermen should avoid standing below an overhead power block or transfer block because of the danger of their being hit by heavy purse rings passing through the blocks. Where such a danger exists, fishermen should wear protective helmets.

7. When handling big catches it is essential to brail or pump the fish on board as quickly as possible to avoid an excessive weight of dead fish in the net.

8. The sinkerline and breastline of the bunt should be so attached to the vessel that they can be quickly released if fish lie too heavily in the net and endanger the stability of the vessel. Preferably, the breastline and that part of the sinkerline which is tied up on the bunt boom and/or on the railing of the vessel, during brailing or pumping, should be fitted with rings through which is released a wire, fixed to the vessel at either end with an easily-released sliphook.

9. When the netting is liberally hung in, the bunt may still retain a heavy weight of fish even after the breastline and sinkerline have been released. It is, therefore, advisable to attach bridles to the bunt floatline so that it can be hoisted up to release the fish.

10. Should the vessel heel over dangerously, and if it is not possible to release the fish, the vessel should be driven ahead and turned towards the listing side. When this does not succeed in righting the vessel, the net should be slacked off immediately or cut.

11. Where the net is stacked in an exposed place it is highly desirable to fit removable stanchions with guard ropes to prevent men from falling overboard.

12. Sea water in the hold causes the fish to become fluid and shift. Care should be taken to separate sea water from the fish during brailing or pumping before the catch reaches the hold, using slanting gratings leading to the hatches. Similarly, blood water seeping from the fish should be pumped out frequently.

13. Fish carried on deck should be covered by double tarpaulins securely fixed, for instance by nailing wooden strips over the edges to the outside of the railing and to fixed pound boards. On steel vessels a wooden plank should be bolted on for this purpose.

14. In an emergency, the skipper should be able to release the deck load through special ports by a quick-release mechanism.

15. When fish are carried on deck, lifelines should be rigged at a suitable height.

16. Where a small auxiliary boat is used, it should always carry light and sound signal equipment in good working order, and the crew should wear lifejackets.

Setting the net, pursing, hauling and stacking

Again reference must be made to Jakob Jakobsson's description in *Modern Fishing Gear of the World 2*, to which the following is meant to supplement:

It goes without saying that the selection of tactics when setting on a school depends on the species and condition of the fish.

1. When setting on a school which swims in a well defined direction, it is preferable to start the set in that same direction and pay out the net in a wide arc well in front of the school, as shown in fig 14(1). It causes difficulties if wind blows in the same direction as the school moves, although this can be overcome on vessels fitted with transverse thrusters or with the assistance of a tow boat.

2. If the fish school is stationary but sensitive (nervous) it may be advisable to set the seine in such a way that the current keeps the net well open during surrounding operation with less danger of coming into contact and alarming the school while pursing (see fig 14(2)).

3. When the fish is scattered, as often is the case during winter herring fishing, and also when setting on schools close to the bottom in shallow water it is advisable to start the set into the current, using long tow ropes and letting the current sweep in the fish while pursing (see fig 14(3)).

The speed of pursing depends obviously on the power of the winch and the length of the seine. In the case of a 300 fm long net, 12 to 15 min is considered a suitable time in the case of method (1) and (2) above, but 20 to 30 min in the case of method (3). The ship should back away while pursing, especially in the case of methods (1) and (2). In the case of method (3) one must give the seine ample time to sink and back very slowly during the beginning of pursing so that the net will reach well down, but back more strongly later to avoid pulling the boat into the seine. Obviously these methods differ according to the types of seines.

In cod and haddock fishing, method (3) has proved effective when these species are found near the bottom in schools of various size.

Capelin schools are usually dense and travel generally with the current as suits method (1).

4. If the vessel has neither transverse thrusters nor helper boat and the school moves downwind, the setting operation is often started with the wind on port bow, the net shot close to the school windward but wide downwind, i.e. aiming to get the fish in the wing end. With this method, one must use a long tow rope off the wing end in order to keep the propeller far from the net during pursing (see fig 14 (4a)). The ship must now back well out of the net during the pursing with alternating ahead to starboard and backing to port. Most Icelandic ships back better to port and all purse to starboard. During pursing there is a danger that the ship will drift onto the wing end because the purseline pulls the boat into the net (see fig 14(4b)). Then it is necessary to haul in the slack wing quickly. Often this is not enough and pursing must be stopped while the slack net is hauled in to

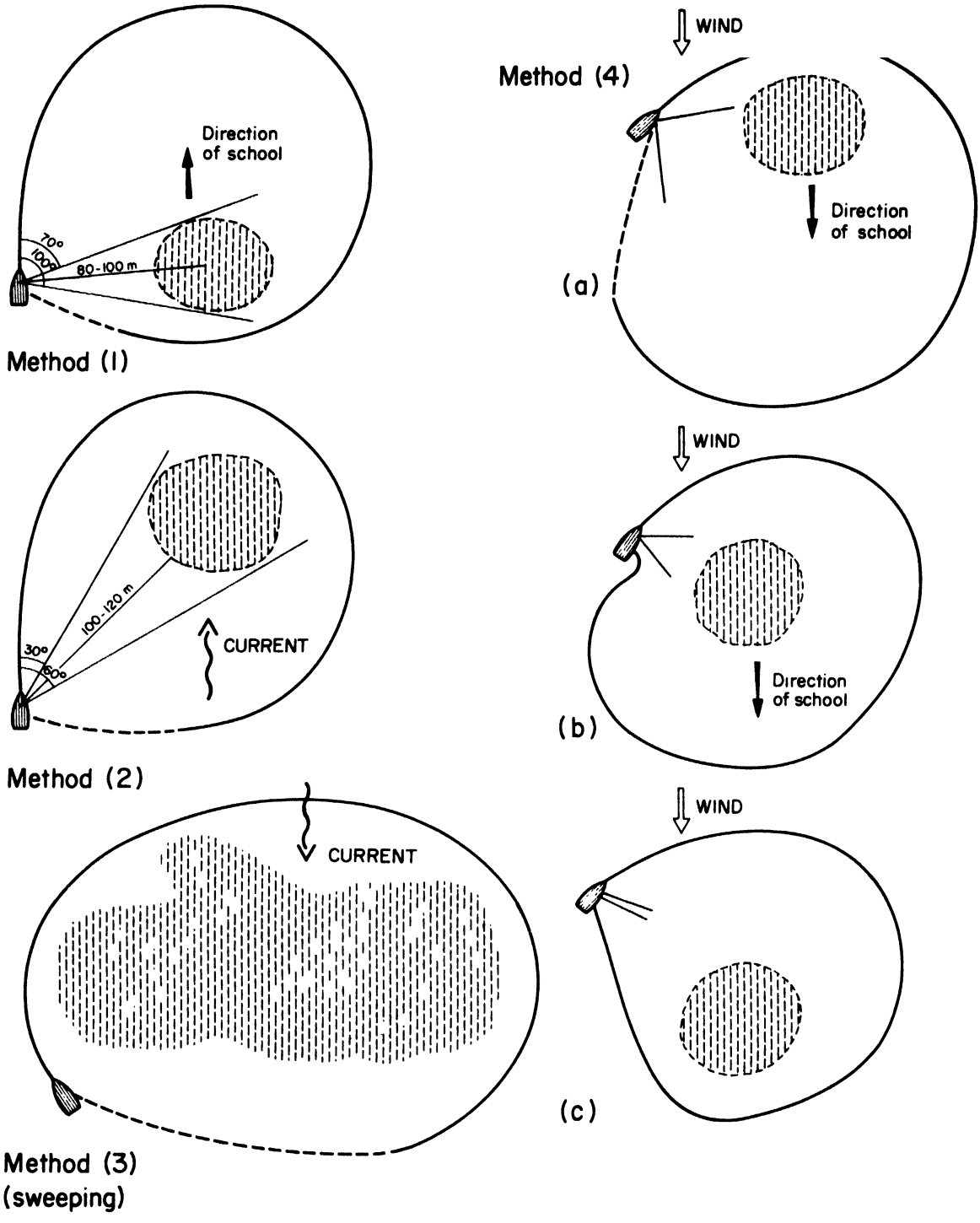

Fig 14

free the stern to avoid getting the net in the propeller when backing (see fig 14(4c)).

Making sets in bad weather (fig 15, 16 and 17) depends greatly on how brave skippers are, and each one must decide how far he wants to risk his gear. Many skippers have managed to catch fish in the open sea in 6 to 8 Beaufort. This is a tough test of the skipper's manoeuvring skill in managing to keep his ship into the wind while pursing, hauling and brailing or pumping. Either bow or stern must face into the wind. Obviously this is far easier on ships with transverse thrusters and then the stern is usually kept into the wind with the main propeller backing slowly. Then the net can be hauled in slack.

Transverse thrusters are a great convenience in purse seining, especially on the bigger vessels. The net wears out less and there is less danger of fouling the netting in the propeller. A transverse thruster at the stern is especially important in vessels with superstructure aft and purse

Fig 15. A big catch is saved in heavy swell by backing into the wind

Fig 16. Hauling the net with a very big catch

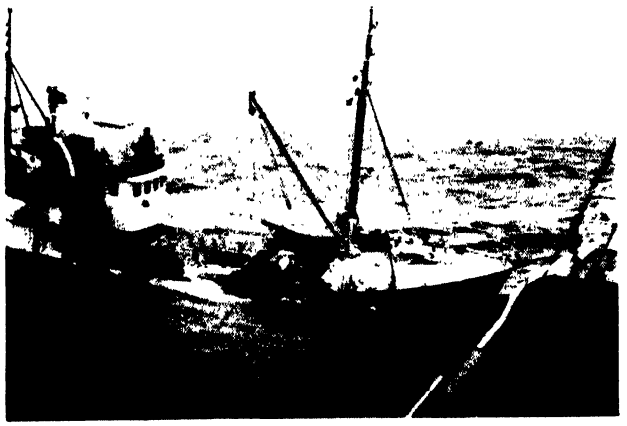

Fig 17. The vessel on the right shelters another during brailing in bad weather

davit forward. A boat fitted with transverse thruster(s) does not need a helper boat, and tow boats or bas boats are not used in Iceland. However, many Icelandic purse seiners carry a small plastic boat or rubber raft with outboard motor for emergency use when something fouls.

A careful man should control the power block because close attention is needed when hauling the Icelandic seines which are hung-in about 50 per cent (2:1). If the net is unevenly hauled, pockets can be formed which fill with fish and cause delays or tearing of the net. To facilitate even hauling, the seines have coloured vertical markerlines at suitable intervals, say every 20 fm. When flaking down the net, the man who coils down the sinkerline must keep the netting well away so the line can run out clear from setting. The netting must be flaked down in bights fore and aft and not form heaps under foot. The man hauling the floatline must also lay it down free from the netting and in bights to avoid it being pulled out in heaps unevenly during setting. It is important that the seine be flaked down evenly, then it takes less space, pays out more smoothly and there is less danger of tearing during setting.

Drying up, brailing or pumping

It is extremely important that the drying up operation proceeds smoothly and quickly when handling a big catch. The net must be hauled in evenly with floatline and leadline at the same rate, otherwise fish bags will form in the netting thus stopping the hauling operation which is dangerous when much fish is in the net, especially capelin and herring which lie heavily in the netting and may sink the bunt, overturning or tearing the net. Many mishaps have been caused in this way. It is better to haul the net slowly and smoothly when drying up to avoid stoppages.

When hauling the net in calm weather, there is a danger that the net may not stay well enough open out away from the ship and the bunt may be pulled down at the side of the ship. Then it may be of tremendous value to have side-thrusters or a tow boat to pull the ship away from the net. But if neither is available, one must try to turn the ship with the propeller at the beginning of the hauling operation in such a way that the current, if there is one, keeps the net open.

After a big catch has been dried up, fish must be brailed or pumped aboard as fast as possible. If there is a stoppage, it is advisable to pay out netting to reduce the danger of fish dying because then it becomes so heavy that even the most powerful blocks and net hauling devices cannot cope with the load, and the netting tears.

TRAINING

It has been explained that Icelandic fishermen were quick to adopt and learn how to use sonar. A major reason is, no doubt, the good cooperation among these skippers where those who first caught on taught the others unstintingly. Furthermore, the Fisheries Association of Iceland organized several courses for skippers which were given by those who had the longest and best experience. Apart from lectures, skippers related their experiences which were then discussed. The functioning of the instruments was explained and minor repairs and troubleshooting taught by electronics technicians.

Without doubt it is possible to obtain good results by teaching on shore present and future skippers the maintenance and use of sonar under various circumstances which are met at sea. Preferably, the teacher must have both (a) sonar instruments for demonstration on shore, and (b) a training ship. Training as described under (a) below is now practised in the Nautical College in Reykjavik.

(a) Teaching on shore is much helped by visual aids, such as slides, film strips and movie films. Useful texts have been produced in recent years, but these need to be supplemented due to the constant modifications and improvements in the sonar units, ship's equipment and the gear itself to fit the changing fishing conditions.

The teacher must also have a sonar unit installed in such a way that it can be easily inspected and explained (fig 18 and 19). Recording paper with various types of echoes can be run through the viewing unit and the sounds played at the same time off a magnetic tape by way of

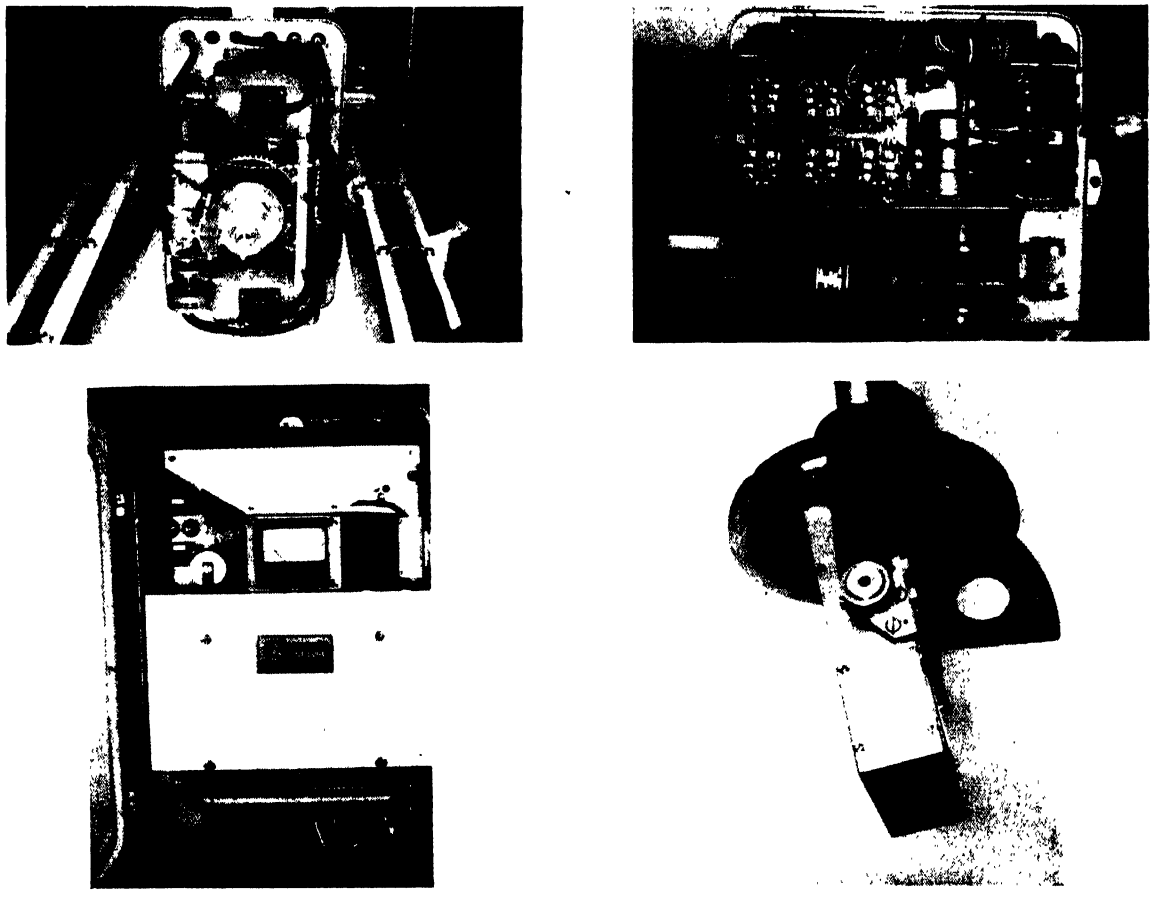

Fig 18. For teaching sonar operation and maintenance on shore, the various instruments must be easily accessible for inspection and adjustment

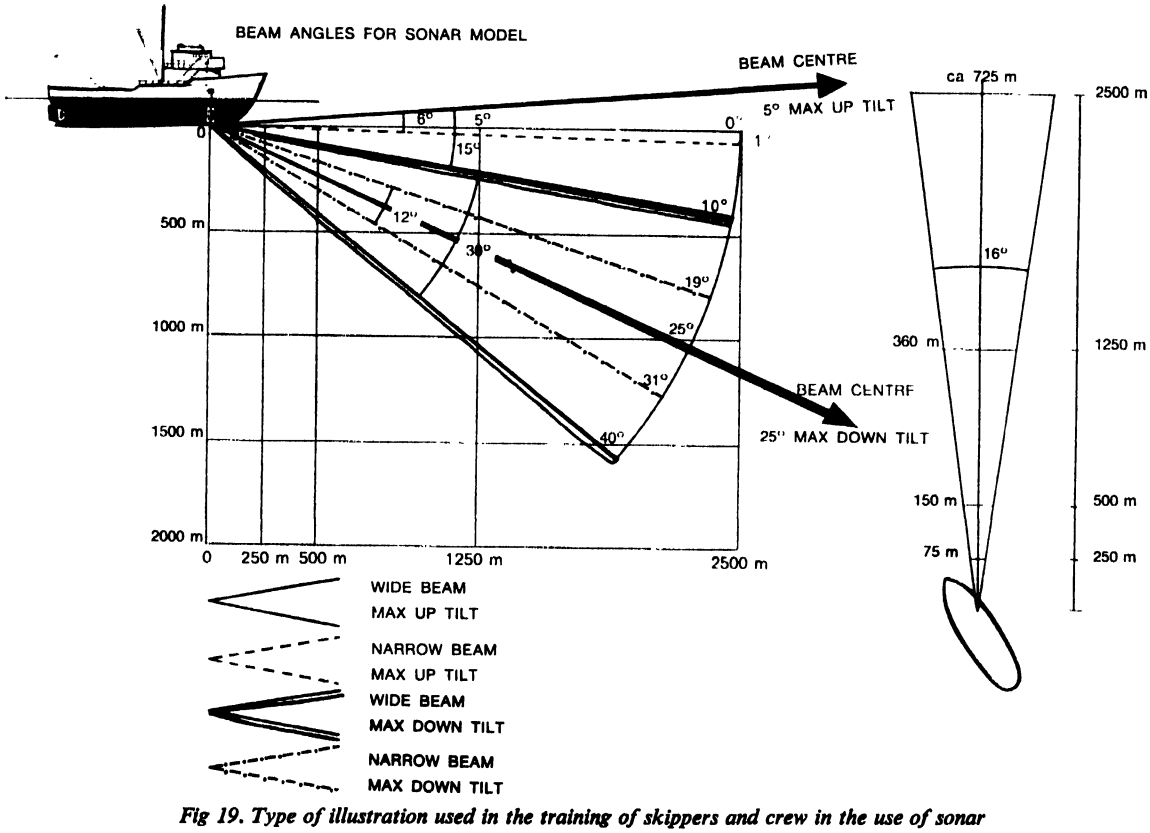

Fig 19. Type of illustration used in the training of skippers and crew in the use of sonar

simulation. The transducer assembly needs to be mounted in a tiltable frame which can be kept vertical for sending and receiving in a water tank for giving training in the operating of sonar and the trainees can see and hear what happens. The entire bottom unit should be tiltable out of water so that the teacher can demonstrate the transducer components and their various reactions to commands from the control panel, also to show how to diagnose faults and how to react to them. Then the golden rule is: do not hesitate to search for defects, but never tear to pieces more than you can assemble again; also test only one thing at a time. If you do not find what is wrong then contact the repair man on shore for guidance, if you can reach him. It is far too expensive to sail long distances back to port with an inoperative instrument if there is any way of repairing it at sea.

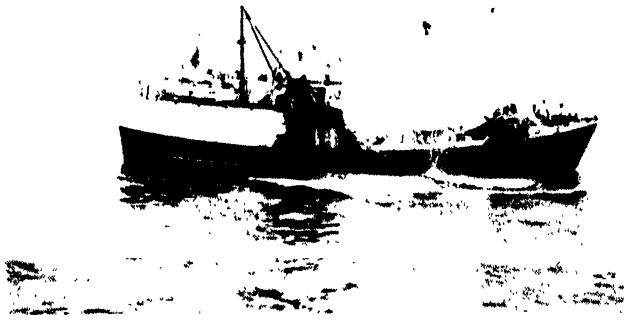

Fig 20. Brailing a large catch

(b) Training ship should have a spacious wheelhouse with good access to the sonar unit, so that it is easy to expand and continue the teaching which started on shore. Since teaching in a training course must keep to a timetable, it is hardly possible to conduct real fishing. Simulation must therefore be used. It is easy to prepare and use

Fig 21. Herring being pumped into a carrier ship on distant grounds. The Icelandic purse seiner fleet operated, in 1968, near Spitzbergen and Bear Island (75 to 76°N) 600 to 900 mi from home

a reflector buoy which can be lowered down to various depths. This reflector buoy can also be moved with a small boat and thus simulate the school moving at various speeds and directions. A floatline of the same length as on the purse seine can be fitted with a buoy and extension line and piled up at the stern. The wheelhouse windows can be covered on the side on which the set is made. The trainees can be taught to locate the school with the sonar unit only, manoeuvre the ship around it, judge and take into account all conditions and set the floatline around the target and retrieve the buoy. This can give good practice in a short time and at low cost, as compared to learning by trial and error in commercial fishing on an expensive ship with a full crew.

The technique can be taught but it goes without saying that to produce a good fisherman one must start with the right human material.

Description of Commercial Icelandic Purse Seines for Herring, Capelin and Cod

Gudni Thorsteinsson

Description des seines coulissantes utilisées en Islande dans la pêche commerciale au hareng, au capelan et à la morue

Le présent document décrit l'expansion connue ces dernières années par la pêche du hareng à la seine coulissante en Islande, ainsi que la construction récente de seines coulissantes pour le hareng. La pêche à la seine coulissante au capelan, nouvelle mais importante, est évoquée plus brièvement. L'auteur donne une description de la fabrication de l'engin de pêche. Il décrit par ailleurs les seines coulissantes destinées à la pêche de la morue pendant la compagne d'hiver, ainsi que celles utilisées par de très petits bateaux en été sur la côte nord pour la pêche aux petits poissons blancs. Les éléments qui ont servi à la préparation de ce document, y compris les dessins de plans, ont été fournis par des fabricants de filets islandais.

Descripción de los artes de cerco empleados en Islandia para la pesca del arenque, el capelán y el bacalao

Se describen los progresos de la pesquería islandesa de arenque con artes de cerco en los últimos años y las redes de cerco para la pesca de arenque construidas recientemente. Se trata brevemente de la pesca del capelán con artes de cerco, iniciada recientemente y ya importante, y se describe la forma de construir el arte empleado. Se describe también la fabricación de las redes de cerco empleadas para la pesca del bacalao durante la estación invernal y la construcción de las empleadas en verano, con embarcaciones pequeñísimas, que pescan en aguas de la costa septentrional, para capturar peces de fondo de pequeño tamaño. Las informaciones contenidas en este documento, incluidos los diseños, proceden de fabricantes islandeses de redes.

THE data dealing with the construction of the Icelandic purse seines for herring, capelin and cod, have mainly been collected from netmakers in the Reykjavik area as lack of time did not allow much correspondence with netmakers in other parts of the country. Other Icelandic netmakers are working in a very similar way.

HERRING PURSE SEINES

The development of Icelandic purse seining up to 1963 has been treated by Jakobsson (1964). A short description of the development of this fishery since that time is necessary to gain a better understanding of recent gear construction.

The successful herring fishery in the early sixties, due mainly to the use of sonar and power block, encouraged Icelandic ship owners to buy new and bigger vessels. These vessels were able to carry greater loads and operate with bigger nets. Their favourable experience resulted in the construction of bigger purse seiners, the development being accelerated by the schools tending to stay progressively in deeper waters each year. This finally forced the smaller vessels to quit the herring purse seine fishery. The seine increased rapidly in size and lead weight, causing serious difficulties for many boats, as the greatly increased gear weight on the boat deck seriously reduced stability. This was solved by cutting away the aft part of the boat deck, thereby obtaining space on the main deck for the net (fig 1). This has proved fairly successful. The greatest disadvantage is the high stern-railing (about 2.5 m) over which the net has to be shot. This increased resistance during shooting, and often caused net damage.

Fig. 1. An Icelandic vessel with a herring purse seine situated far aft on the main deck (photo Halldór Dagsson)

TABLE 1. PARTICIPATION, AVERAGE SIZE, CATCH, CREW SIZE AND NUMBER OF FISHING DAYS PER VESSEL IN THE ICELANDIC SUMMER AND AUTUMN HERRING SEASONS (ANON. 1961–1969)

Year	*No. of ships*	*Average size BRT*	*Average catch (T)*	*Crew size*	*Fishing days*
1961	220	86	950	11.0	67
1962	224	100	1420	10.9	75
1963	226	109	1010	11.5	87
1964 (to Oct. 30)	233	133	1395	11.8	97
1965	234	145	2747	11.4	163
1966	202	175	3620	11.9	174
1967	168	220	2495	12.3	168
1968	119	258	1153	12.5	134
1969 ca	50				

The increased bulkiness and weight of the bigger net and gear required more powerful purse winches and bigger power blocks.

Table 1 illustrates this development. Comments are unnecessary, but the correlation between the increased vessel size and the extension of the season in autumn should be underlined. In 1962 the majority of the vessels were using power blocks, and all of them used sonar.

Construction

The usual length of the net now is 250 to 300 fm[1] (470 to 565 m) which is the length of the floatline except for the power block choke. The leadline is about 30 to 50 fm (57 to 94 m) longer depending on the difference in hanging ratio between the upper and lower lines. The maximum stretched net depth is most frequently 100 to 120 fm (188 to 226 m). Because of the rapid increase in net size in recent years, many smaller seines are available and for economical reasons are sometimes used.

The shape of the net is unique. The bunt is most frequently cut 1 m 2 b on the lower edge, the all bar cutting rate shown in fig 2 being uncommon. From the bunt, the following panels are cut all bar until 80 to 90 per cent of the maximum depth has been achieved. Henceforth the following 1000 mesh panels increase some 1 to 2 fm in depth each. By lacing these panels, this depth difference is equalized on the lowest one-third of the panels or even over a smaller portion of the panels. The middle panel is usually 2000 meshes long, sometimes 3000 meshes, but seldom only 1000 meshes (fig 3). The panels on the wing side of the middle (right on the drawings) are more or less congruous with the panels of the left side, except the three or four last ones.

Due to the great depth of the last wing panel, it is necessary to use a power block choke to get the floating

[1] The term fathom always refers to the Norwegian fathom (188.4 cm).

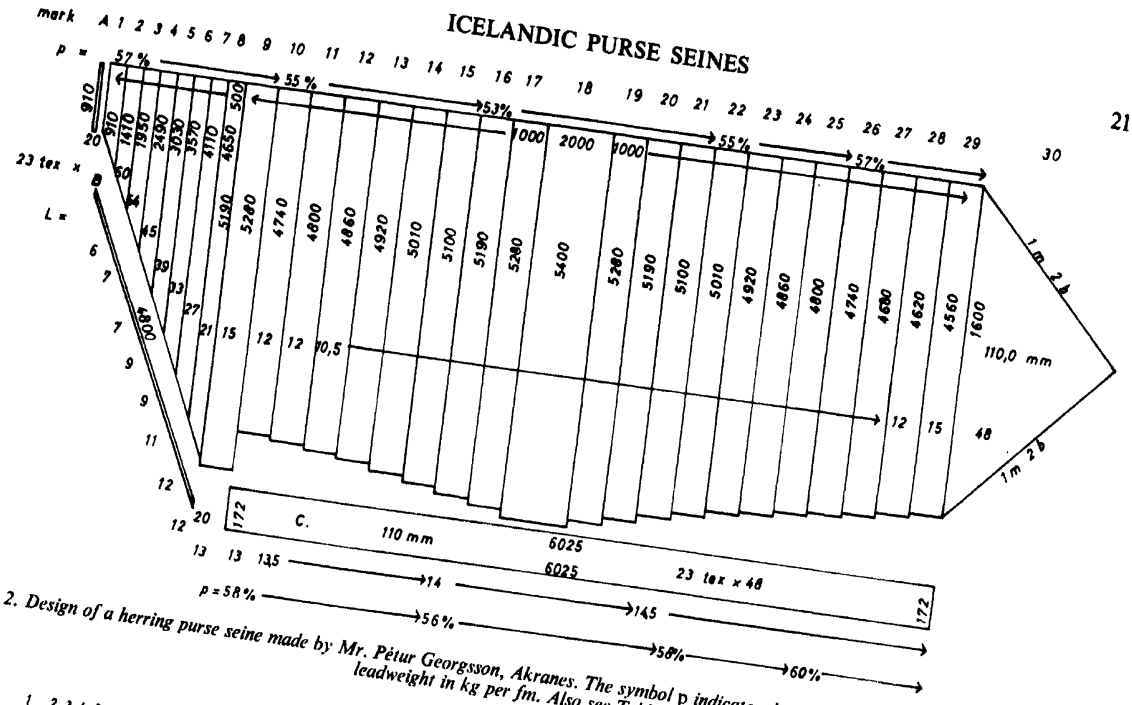

Fig 2. Design of a herring purse seine made by Mr. Pétur Georgsson, Akranes. The symbol p *indicates the hanging ratio in per cent and* L *the leadweight in kg per fm. Also see Table 2.*

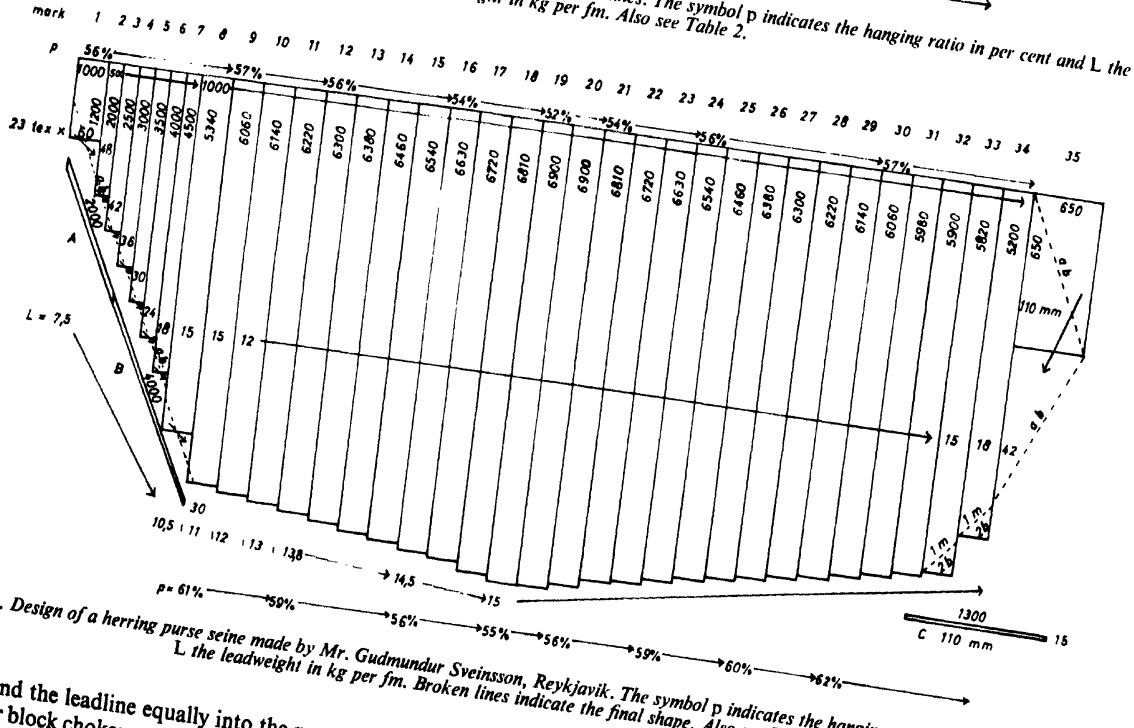

Fig 3. Design of a herring purse seine made by Mr. Gudmundur Sveinsson, Reykjavik. The symbol p *indicates the hanging ratio in per cent and* L *the leadweight in kg per fm. Broken lines indicate the final shape. Also see Table 3.*

line and the leadline equally into the power block. These power block chokes were first used in 1964. The triangular isosceles shape (figs 2 and 3) is by far the most widespread. The right angle triangular shape, with the shortest side extending the floatline, is not very common now. The reversed triangular shape where the shortest side extends the leadline is not very common now. Ordinarily, lead is not used on the power block choke and only a few floats are used. From the outermost angle a breastline of up to 120 fm length (polypropylene Z 32 mm dia or polyamide Z 24 mm dia) runs to the ship. Before the power block chokes were used, the wing breast was often pulled together with a breastline running through thimbles distributed along the breast edge.

By far the most common mesh opening is 31.4 mm. Sometimes, 39.4 mm meshes are used in the summer fishery of the Atlantic-Scandian herring. The power block choke is, however, of 110 mm or similar mesh size, and frequently a long net panel of this mesh size is sewn below the ordinary panels as shown in fig 2 (netting piece C). The purpose of this net panel is to decrease the resistance during pursing. Such a construction was first

TABLE 2. SELVEDGE OF A HERRING PURSE SEINE DESIGNED BY PÉTUR GEORGSSON INCLUDED IN THE TOTAL NUMBER OF MESHES (SEE FIG 2)

1–3 and A–B top and bottom:	20 meshes	5/72, 5/80, 5/96, 3/120, 2/144
4–6 top and bottom:	20 meshes	5/54, 5/72, 5/90, 3/120, 2/144
7–8 bottom:	20 meshes	5/36, 5/54, 5/72, 3/90, 2/120
7–9 top:	30 meshes	5/36, 5/48, 5/60, 5/72, 3/81, 3/96, 2/120, 2/144
9 bottom:	70 meshes	20/18, 10/27, 10/36, 10/48, 10/6C, 3/72, 3/81, 2/96, 2/120
10–12 and 28 top:	170 meshes	100/15, 20/18, 10/27, 10/36, 10/48, 10/60, 3/72, 3/90, 2/120, 2/144
13–27 top:	370 meshes	200/12, 100/15, 20/18, 10/27, 10/36, 10/48, 10/60, 3/72, 3/90, 2/120, 2/144
29 top:	70 meshes	20/18, 10/27, 10/36, 10/48, 10/60, 3/72, 3/90, 2/120, 2/144
10–28 bottom:	115 meshes	100/15, 3/18, 3/24, 3/30, 3/36, 3/42
29 bottom and one side:	15 meshes	3/18, 3/24, 3/30, 3/36, 3/42
C top, bottom and both sides:	14 meshes	2/60, 2/72, 2/81, 2/90, 2/96, 2/120, 2/144
30 top and bottom:	20 meshes	5/60, 5/72, 5/90, 4/120, 1/144

used in the winter fishery in 1947 due to lack of netting with smaller meshes. The outermost half meshes of the whole net are mostly 30 mm bar.

Material used

The only material used is knotted polyamide dyed black and impregnated with tar, always with vertical meshes. The twine number 23 tex × 6 was commonly used for small nets until 1961. During the next 3 to 4 years, the thin yarn was mostly replaced by 23 tex × 9 twine. The use of twine number 23 tex × 10.5 became widespread in 1965 to 1966. The 23 tex × 12 yarn, most common at the present time, came first into use in 1964. The stronger twine numbers in the bunt and adjacent panels (figs 2 and 3), are typical for the Icelandic herring purse seines in general. The guardings (selvedge) of those nets shown in Tables 2 and 3 also characterize the common Icelandic type of nets.

TABLE 3. SELVEDGE OF A HERRING PURSE SEINE DESIGNED BY GUDMUNDUR SVEINSSON INCLUDED IN THE TOTAL NUMBER OF MESHES (SEE FIG 3)

1–3 top and one side of 1 and A:	30 meshes	10/72, 10/84, 7/90, 2/120, 1/144
4–7 top and B:	30 meshes	6/48, 7/60, 7/75, 7/90, 2/120, 1/144
8–9 and 33 top and bottom:	220 meshes	120/18, 50/21, 10/27, 10/36, 5/42, 5/48, 5/60, 7/72, 5/90, 2/120, 1/144
10–32 top:	470 meshes	250/15, 120/18, 50/21, 10/27, 10/36, 5/42, 5/48, 5/60, 7/72, 5/90, 2/120, 1/144
10–32 bottom:	300 meshes	140/15, 60/18, 50/21, 10/27, 10/36, 5/42, 5/48, 5/60, 7/72, 5/90, 2/120, 1/144
35 top:	50 meshes	30/48, 5/60, 5/75, 5/90, 4/120, 1/150
C:	15 meshes	5/75, 5/90, 4/120, 1/150

Sometimes, reinforcements of 23 tex × 15 to 18 meshes lengthwise with 50-mesh intervals depthwise have been used to meet the varying conditions during fishing operations. These reinforcements have, however, hardly met requirements.

A successful attempt to reinforce the netting is by vertical strengthening lines between the floatline and the leadline, but the placement of these lines require to pass through the strands of the ropes to prevent slippage. If some shrinkage or elongation of the ropes (or the netting) occurs, the lines have to be refastened to the net.

Hanging ratio[2]

It is a common belief in Iceland that a hanging ratio above 60 per cent will influence the catchability of the gear in a very negative way, as such a high hanging ratio does not permit the netting to achieve the desired bag-formed shape during pursing, with the consequence that the school will be herded under the vessel by the netting. Therefore, a hanging ratio of 52 to 56 per cent is the most frequently used for the middle of the net. Bunt and wings are hung about 60 per cent.

The hanging ratio of the leadline is about 2 to 6 per cent higher than that of the floatline. Thus the length difference of each 1000 mesh panel can be 1 fm and in exceptional cases even higher. The explanation of this difference—mathematically much too great—is that the power block normally hauls the leadline faster than the floatline. A floatline that is too slack increases the danger that the catch will be hauled over it and thus lost. A skilled mate working with a good power block can, however, easily accomplish an equal hauling of both lines of a net with much less length difference. Consequently, the length difference of the lines has been decreased recently.

Floats, lead, ropes etc.

On each fathom of the floatline 5 to 6 plastic floats with holes are used, having a total buoyancy of some 14 kg. On the bunt, however, more and bigger floats are used. On the upper side of the power block choke hardly more than three floats per fm are used.

The floats are strung on a 14 or 16 mm dia Z twisted polypropylene rope. The real upper line consists of two polyester ropes usually 16 mm dia, of which at least one is Z twisted. The netting is hung all around to 8 mm dia polyester Z twisted ropes. Thus the floatline consists of four lines (fig 4).

The lower line is heavily weighted with oval-shaped lead pieces with holes, each piece normally weighing 1000 or 1500 g. The total weight per fathom increases

[2] The expression commonly in use in Iceland is the percentage hanging-in-ratio. In this paper, however, the expression "hanging ratio" is used.

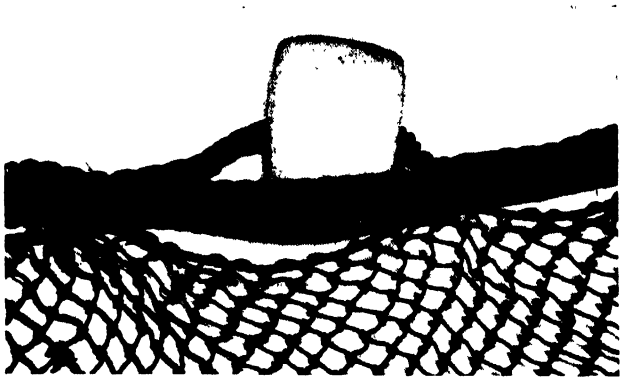

Fig. 4. Floatline arrangement of an Icelandic herring purse seine (photo Halldór Dagsson)

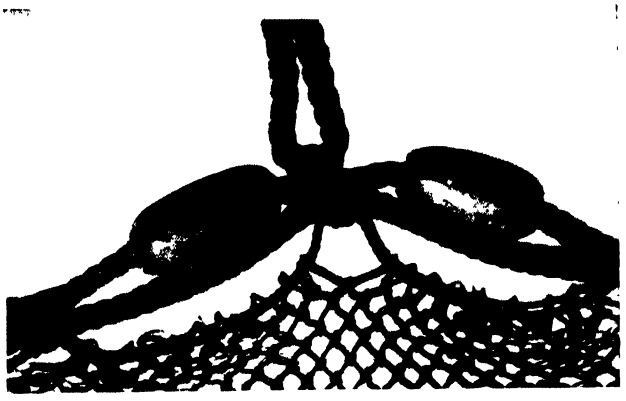

Fig. 5. A leadline of a herring purse seine. The attachment of a purse ring strop is shown (photo Halldór Dagsson)

from about 4 kg on the bunt up to 12 to 15 kg on the middle and on the wing.

The leadline consists of two polyester ropes, usually of 14 mm dia each, of which at least one is Z twisted. The lead pieces are strung on the lower one of these two ropes (fig 5).

The bunt breastline consists of two or three 10 mm Z or S twisted polyester ropes (fig 6), and the wing breastline and the edge lines on the power block choke as well (fig 7). Figure 8 shows the arrangement of the purse ring strops.

The nets shown in figs 2 and 3 can be considered typical Icelandic herring purse seines without any extremes in hanging ratio, lines difference or other items.

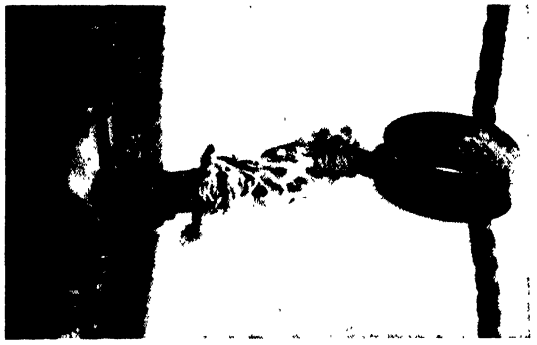

Fig. 6. A bunt breastline of a herring purse seine (photo Halldór Dagsson)

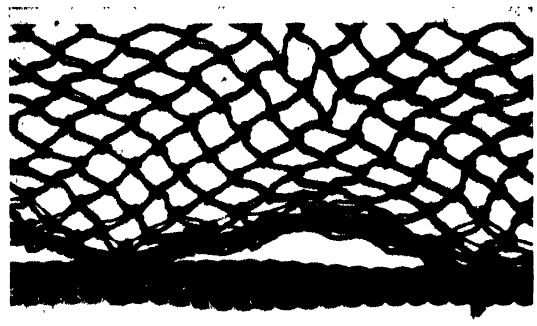

Fig 7. The edge of a power block choke (photo Halldór Dagsson)

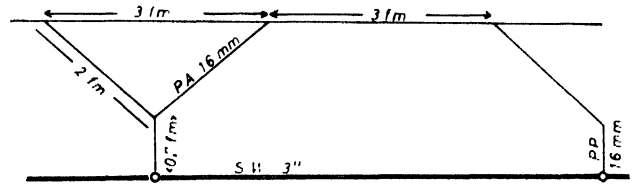

Fig. 8. Dimensions and arrangement of the purse ring strops

CAPELIN PURSE SEINES

Capelin has been caught for bait in small purse seines or or even beach seines for many years. The first attempts to catch this species for reduction purposes with specially-constructed purse seines were made in 1964. Since then, about 40 to 60 purse seiners have caught capelin during their spawning migration westward along the south and southwest coast, mainly in February and March. Table 4 shows the total annual catch from the beginning of this important fishery and the participation.

TABLE 4. TOTAL ANNUAL CATCH CAPELIN IN METRIC TONS AND THE PARTICIPATION IN THE FISHERY (ANON. 1964–1969)

Year	*Catch (T)*	*Number of vessels*
1964	8.639	?
1965	47.887	35
1966	124.933	66
1967	96.800	50
1968	77.718	40
1969	170.561	48

Construction

No basic construction changes have taken place in the last years, except in connection with the "bottom purse seines" (Thorsteinsson, 1970). However, the dimensions have increased somewhat since 1964, the length at that time being about 120 fm (226 m), and the stretched depth rarely exceeding 30 fm (57 m). At present, the most common size is 140 to 150 fm (264 to 283 m) in length and 35 to 40 fm (66 to 75 m) in depth. Thus the length–depth ratio is approximately 1 : 4 compared with 1 : 2.5–1 : 3 in the herring purse seine construction. Therefore, the bunt and the following panels of the capelin purse seines are seldom cut all bar like the herring seines but most frequently 1 m 2 b.

Otherwise the construction is very similar to that of herring nets. All lines are of the same strength and

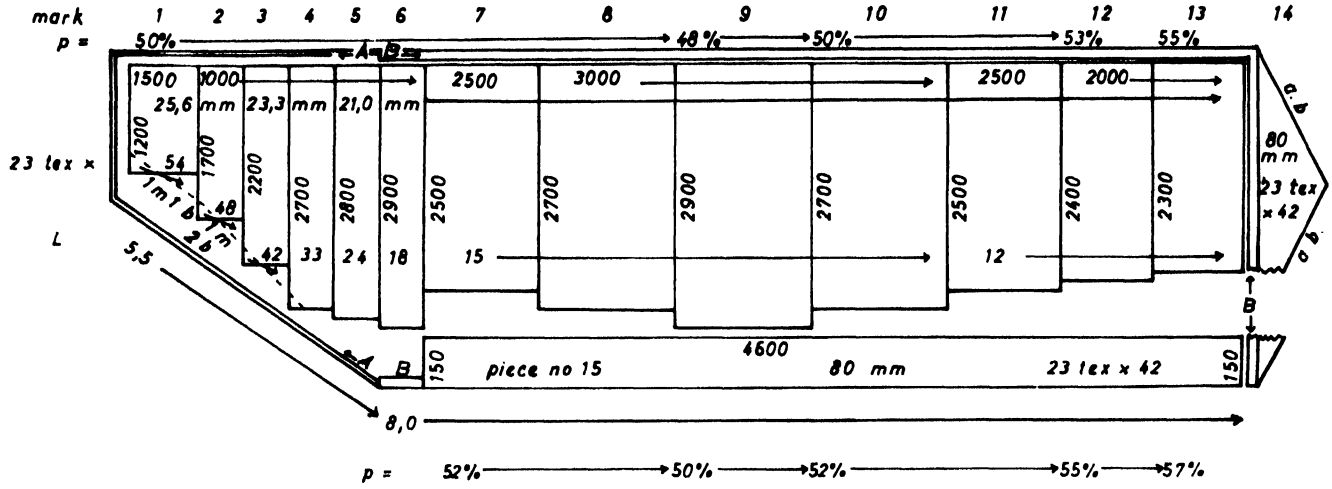

Fig 9. Design of a capelin purse seine made by Mr. Sigurdur Pétursson, Hafnarfjördur. The symbol p *indicates the hanging ratio in per cent and* L *the leadweight in kg per fm. Broken lines indicate the final shape. Also see Table 5*

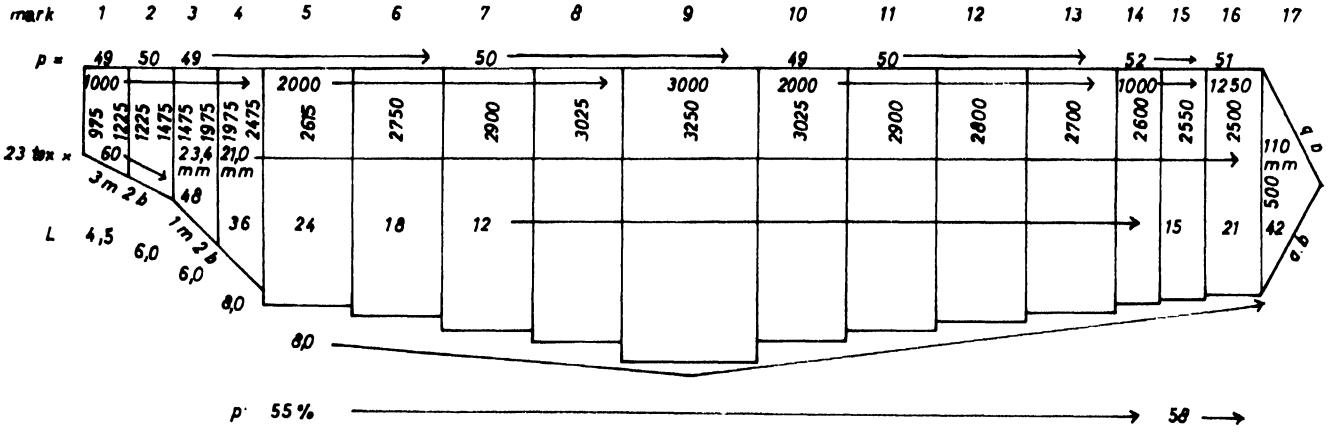

Fig 10. Design of a capelin purse seine made by Mr. Thorberg Einarsson, Reykjavik. The symbol p *indicates the hanging ratio in per cent and* L *the leadweight in kg per fm. Also see Table 6*

material and attachments of lines to the net is as described for herring seines. The lead weight increases from about 4 to 5 kg/fm on the bunt up to 8 to 10 kg/fm on the middle and wing. The same kind of floats are used, but increased number per unit length. About 12 floats to the fathom are used from the bunt to the middle or even further, whereas 6 to 9 floats to the fathom are fastened on the wing section. This great buoyancy is necessary since the capelin schools lie very heavily in the netting, so that the net often becomes submerged if the school is large. In this way, part of the school can be lost. Still more floats could prevent this, but then the net would no doubt tear and the entire catch escape.

In 1964, the nets were made of 23 tex × 9 yarn, but, owing to the heavy pressure of fish against the net, stronger twine numbers had to be introduced. Now 23 tex × 12 is commonly used in the wing part and often in the middle as well. In the remaining parts of the net, at least 23 tex × 15 twine is generally used.

Because of the heavy hauling necessary in the capelin fishery, the use of pumps is very advantageous, since pumping can start before the school has been hauled to the surface. This prevents unnecessary stress on netting and saves time.

Figures 9 and 10 show two typical Icelandic capelin purse seines of new design. The hanging ratio indicated is that commonly used. The guardings of these nets are shown in Tables 5 and 6. Note the "loose selvedge" of the design (fig 9, net pieces A and B).

TABLE 5. SELVEDGE OF A CAPELIN PURSE SEINE DESIGNED BY SIGURDUR PÉTURSSON INCLUDED IN THE TOTAL NUMBER OF MESHES (SEE FIG 9)

A:	20 meshes*	5/60, 5/84, 5/96, 4.5/120, 0.5/144
B:	40 meshes*	10/33, 10/48, 5/60, 5/84, 5/96, 4.5/120, 0.5/144
15 top and bottom:	10 meshes	3/60, 3/84, 2/96, 1.5/120, 0.5/144
6 top and bottom:	135 meshes	135/21
7–10 top:	270 meshes	135/18, 135/21
11–13 top:	360 meshes	90/15, 135/18, 135/21
14 top and bottom:	10 meshes	3/60, 3/84, 2/96, 1.5/120, 0.5/144

* The whole depth.

TABLE 6. SELVEDGE OF A CAPELIN PURSE SEINE DESIGNED BY THORBERG EINARSSON INCLUDED IN THE TOTAL NUMBER OF MESHES (SEE FIG 10)

1–2 top and bottom one side of 1:	25 meshes	18/72, 4/90, 2/120, 1/150, 31.4 mm
3 top and bottom:	25 meshes	13/60, 5/72, 4/90, 2/120, 1/150, 31.4 mm
4–6 top and bottom	25 meshes	8/48, 5/60, 5/72, 4/90, 2/120, 1/150, 31.4 mm
7–15 top and bottom:	260 meshes	21.0 mm, 200/18, 50/24, 10/36,
	21.5 meshes	31.4 mm, 10/48, 5/60, 5/90, 1/120, 0.5/150
16 top, bottom and one side:	60 meshes	21.0 mm, 50/24, 10/36
	21.5 meshes	31.4 mm, 10/48, 5/60, 5/90, 1/120, 0.5/150
17 three sides:	15 meshes	3/48, 3/60, 2/72, 2/90, 2/102, 2/120, 1/150

COD PURSE SEINES

Purse seiners of similar size as in the herring and capelin fishery sometimes operate with cod purse seines during the peak winter season. Another purse seine fishery for cod is important for very small vessels off the north coast in summer.

Good cod catches obtained in herring purse seines in April 1963 indicated that purse seining could be very effective on spawning cod. In the following two seasons the catch in specially constructed cod purse seines was excellent (Table 7). After that, this fishery soon lost its significance.

TABLE 7. THE TOTAL ANNUAL LANDINGS OF COD IN METRIC TONS CAUGHT IN PURSE SEINES IN THE YEARS 1963–1969, AND THE PERCENTAGE OF THE TOTAL WHITE FISH CATCH OF THE WINTER SEASON (ANON. 1963-1969)

Year	*Catch (T)*	*Percentage of the winter season catch*
1963	5.421	2.7
1964	40.808	15.2
1965	35.696	16.5
1966	13.464	6.5
1967	5.905	3.3
1968	3.601	2.0
1969	1.300	0.6

TABLE 8. SELVEDGE OF A COD PURSE SEINE DESIGNED BY KRISTINN O. KARLSSON INCLUDED IN THE TOTAL NUMBER OF MESHES (SEE FIG 11)

1 and 2 top and bottom and one side of 1:	8 meshes	2/72, 2/84, 2/102, 1/120, 1/144
3 and 4 top and bottom:	15 meshes	5/45, 2/60, 2/72, 2/84, 2/102, 1/120, 1/144
5–10 top and bottom and one side of 10:	15 meshes	3/36, 2/45, 2/60, 2/72, 2/84, 2/102, 1/120, 1/144

In the 1964 winter season, ten vessels caught more than 1000 metric tons of cod and roughly the same amount of herring in addition. The top boat *Sigurpáll* landed 1.500 metric tons of cod and 2.300 metric tons of herring during a period of four months, entirely caught with purse seines. Many vessels fished early in the season with gillnets and later, at the peak of season, with cod purse seines. During April 16–30, 1964 some of the purse seiners caught 400 to 600 metric tons of cod each, compared with a catch of 200 to 250 metric tons obtained by the top gillnetters. Purse seining is extremely effective in the cod fishery, if the schools are dense enough. In later years, scattered occurrence of cod did not permit successful purse seining, although the catch of gillnetters was satisfactory.

A peculiar feature of the 1964 season was the extraordinary size of the cod caught with purse seines. The explanation probably is that this cod was above the selection range of the gillnets. Another possibility is that the bigger fish were mainly distributed above the bottom set nets (Thorsteinsson, 1965).

As the cod purse seines still in use were mainly rigged in 1964 and 1965, there are no important differences in construction. Figure 11 shows the characteristic cod purse seines in use with the exception that later power block chokes of the construction already described were sewn to the nets. No noticeable variations in lead weight, hanging ratio and shape exist. Lines and rigging are identical with the herring purse seines. The only variable item is the floating. As the tactics of the cod purse seining was to submerge the net to the bottom, only three floats were normally used on the fathom. A total submerging was prevented by large balloons fixed to the float line by means of strops of adequate length.

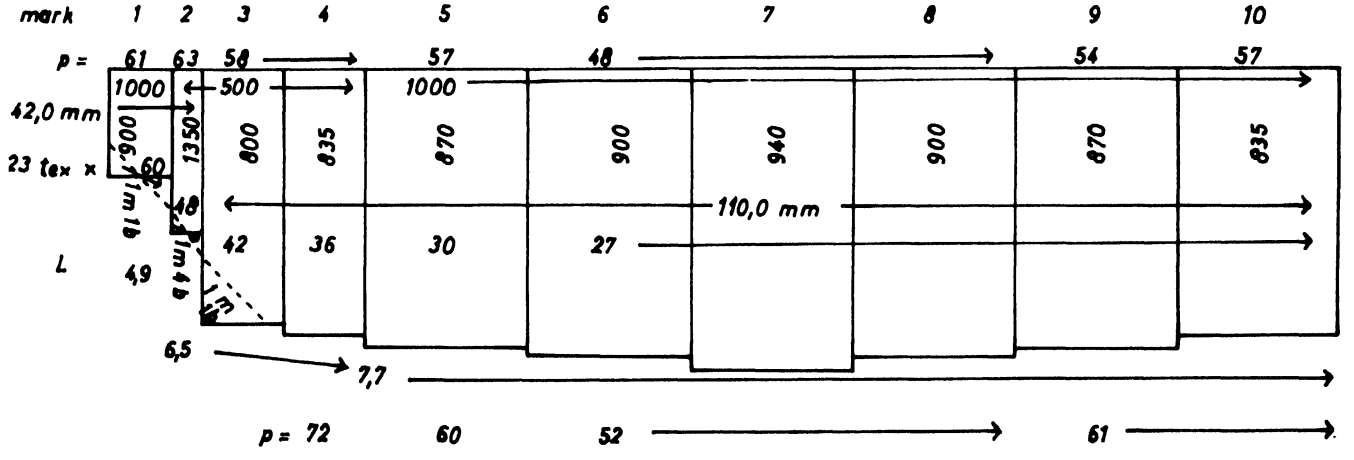

Fig 11. A design drawing of a cod purse seine made by Mr. Kristinn O. Karlsson, Hafnarfjördur. The symbol p *indicates the hanging ratio in per cent and* L *the leadweight in kg per fm. The broken line indicates the final shape. Also see Table 8*

Summer season

During the spring and summer months, a combined cod and haddock purse seine fishery off the Icelandic north coast is of importance for a small fleet of vessels ranging in size from 2 to 40 GT. Because of the tonnage difference, the net dimensions are very variable. Figure 12 shows a net, characteristic for 2 to 5 GT open boats operating in the inner reaches of Eyjafjördur. Figure 13 shows a net for boats of about 25 to 35 GT size. As can be seen, the construction of these seines is somewhat different depending on the size. Because of the smallness of these seines, the netting for each gear is not bought separately. When rigging the nets, the exact depth of each panel is obtained by cutting from deeper net panels of the desired length, and the mesh number depthwise is not counted. For that reason the depth of each panel is given in fathoms of stretched netting.

Included in the depth of the net shown in fig 12 is a 1 ft deep selvedge on the lower edge consisting of 23 tex × 36 polyamide of 40 mm mesh opening. On the upper edge, only one row is of stronger twine (23 tex × 36). The plastic floats are oval-shaped with a hole, each having a 200 g buoyancy. The lead pieces are spheres weighing 160 g each. A total of 15 purse ring strops 2½ fm in length each, consisting of 7 mm dia polyester, are fastened to the lower line. The leadline consists of two polyester ropes, 5 and 7 mm dia, and the breastlines of two 4½ mm dia polyester lines. The floatline consists of two 5 mm polyester ropes and one 4½ mm line on which the floats are strung.

On the net shown in fig 13, a selvedge of ½ fm depth, made of twine numbers 23 tex × 36 to 90, is sewn to the main netting all round. The mesh size is 40 mm on the lower side, but elsewhere 110 mm. The line arrangement is similar to that of the smaller nets, the polyester lines, however, being 10 mm dia. Sometimes, polyethylene and polypropylene of similar breaking strength are used. On the bunt and its nearest panel four 9 in. floats are used to the fathom, on the remaining panels three floats are used to the fathom.

Because of the small size of the fish caught, the mesh size is a real problem. The 110 mm mesh size of all the netting except the bunt results in very frequent gilling of small fish. By using smaller meshes, big quantities of undersized fish might be caught, but by a cautious brailing operation this fish certainly would survive. The construction with the bunt in the middle (fig 12) does not mean that this gear is shot by two boats. The aim is to prevent gilling as far as possible since the catch in this case is herded only along half the net. Consequently, after each set, half of the net has to be hauled over in order to be ready for shooting again. Therefore, this construction is not very common.

All the boats are equipped with echo sounders, but very few with sonar. After having found a school, a weighted float is thrown overboard, around which the

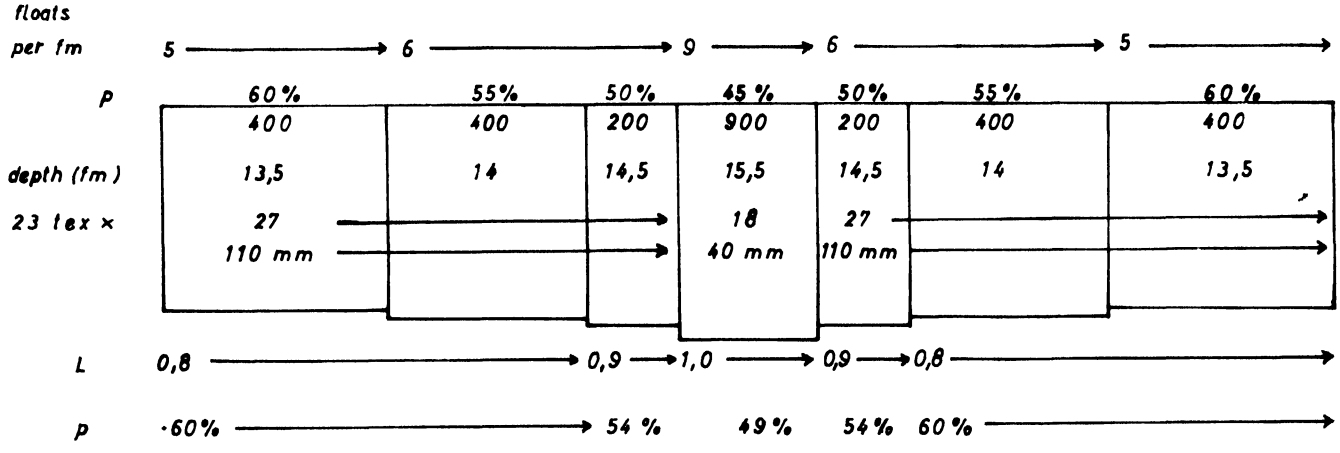

Fig 12. A drawing of a cod purse seine for 2 to 5 BRT open vessels made by Mr. Hjörtur Fjeldsted, Akureyri

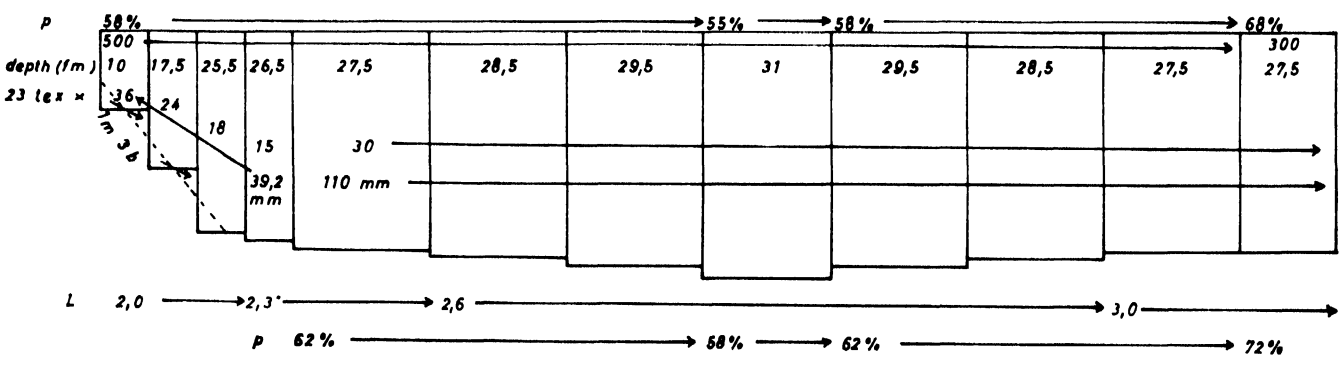

Fig 13. A drawing of a cod purse seine for 25 to 35 BRT cutters made by Mr. Porvaldur Gudjonsson, Akureyri. The broken line indicates the final shape

net is then shot. Sometimes two boats cooperate. In that case, one of the boats equipped with an echo sounder stays above the school until the second one has shot the net around it. Small mechanical purse winches are commonly available. Sometimes, in the case of smaller boats, manual winches are used. During pursing, the vessels have to be anchored in order to stay clear of the net. In the case of cooperation of two boats, the search boat sometimes purses by steaming with one end of the purse line away from the catch boat. Power blocks are not generally used. (Personal communication from Hjörtur Fjeldsted, Akureyri.)

The season starts in late April and lasts as long as schools can be found, usually until late July. If the fish is scattered, the vessels take up other fishing gear, such as handlines or Danish seines. The average catch of boats above 20 GT is in most years more than 200 metric tons, whereas the smallest open boats seldom exceed 50 metric tons each.

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Technological Aspects of the Modern Norwegian Purse Seine Fisheries

J. Hamre, O. Nakken

Aspects technologiques des pêcheries norvegiennes modernes à la senne coulissante

Les plus importantes espèces capturées sont le hareng, le maquereau et le capelan, qui sont essentiellement destinés aux industries de transformation. La pêche à la senne coulissante, d'origine suédoise, a été introduite en Norvège au début du siècle et a par la suite été fortement influencés par les pratiques américaines et islandaises. Avec l'introduction de la poulie mécanique (power block) en 1963–64 et d'autres dispositifs méchaniques de relevage, la méthode à deux doris a été remplacée par la méthode à un seul bateau; parallèlement, la dimension des navires et des filets a considérablement augmenté. Cette pêche exige l'assistance de remorqueurs ou l'emploi d'hélices de poussée latérale (à l'avant et à l'arrivère), hélices dont sont aujourd'hui équipés de très nombreux grands bateaux. Les navires sont évidemment dotés de l'équipement le plus récent en matière de détection (sonars, échosondeurs) et de navigation. Les dimensions des bateaux varient entre 70 et 80 pieds environ pour la pêche côtière et entre 80 et 190 pieds environ pour la pêche hauturière, avec une capacité de charge allant jusqu'à 700 t. Les filets sont essentiellement fabriqués en nylon, à fils noués pour les grandes sennes (environ 600 × 150 m) à hareng et maquereau, et à fils sans noeuds (Raschel) pour les petites sennes (environ 400 × 75 m) et les sennes à petites mailles utilisées pour les sprats et les capelans. Le pourcentage d'armement est approximativement compris entre 40 et 50 pour cent. Etant donné que les stocks de harengs et de maquereaux semblent en diminution et sont protégés, la pêche aux capelans apparaît très prometteuse pour le proche avenir. On tend de manière générale à réduire le nombre des bateaux de petite taille et à constituer une flotte comportant un nombre relativement faible de grands navires ayant une forte capacité de charge.

Aspectos technologicos de las modernas pesquerias noruegas con redes de cerco

Las especies más importantes capturadas son arenque, jurel y capelán, que se emplean, sobre todo, para la obtención de harina y aceite. La pesca de cerco fue introducida, procedente de Suecia, a principios del siglo y más tarde sufrió fuertes influencias de los Estados Unidos e Islandia. Con la introducción de la polea mecánica (1963–64) y otros instrumentos mecánicos para el halado de la red, el método de pesca de cerco con dos botes fue sustituído por el método de pesca con una sola embarcación y al mismo tiempo el tamaño de las embarcaciones y las redes aumentó considerablemente. La operación requiere la ayuda de un bote remolcador o de hélices de empuje lateral (proa y popa), con las que hoy día están ya equipadas muchas grandes embarcaciones. Los barcos elevan, como es natural, equipo modernísimo de sonar, sondeo acústico y navegación. El tamaño de las embarcaciones va de 70 a 80 pies de eslora, para la pesca de bajura, y de 80 a 190 pies para la pesca de altura, con capacidades de carga de hasta 700 toneladas. Las redes son predominantemente de nilón; en las redes grandes (de unos 600 × 150 m), empleadas para el arenque y el jurel, se utilizan paños anudados, mientras en las redes más pequeñas (de unos 400 × 75 m) y de malla más estrecha, empleadas para el espadín y el capelán, se utilizan paños sin nudos (Raschel). El coeficiente de armadura oscila entre el 40 y el 50 por ciento. Como las poblaciones de arenque y jurel parecen ir disminuyendo y están protegidas, la pesquería del capelán parece ser la más prometedora para el próximo futuro. En general, se tiende a una reducción del número de embarcaciones pequeñas y a formar una flota constituida por un número relativamente reducido de embarcaciones grandes, con mayor capacidad de carga.

THE species fished by Norwegian purse seiners are herring (*Clupea harengus*), sprat (*Clupea sprattus*), capelin (*Mallotus villosus*), mackerel (*Scomber scombrus*), bluefin tuna (*Thunnus thynnus*), coalfish (*Gadus virens*) and polar cod (*Gadus saida*). The most important fisheries are the herring fishery which takes place along the whole Norwegian coast, the mackerel fishery off the southern coast, and the capelin fishery off the north coast of Norway. The bulk of the purse seine catches has so far been used for industrial purposes (i.e. reduction).

The purse seine has been used by the Norwegians since

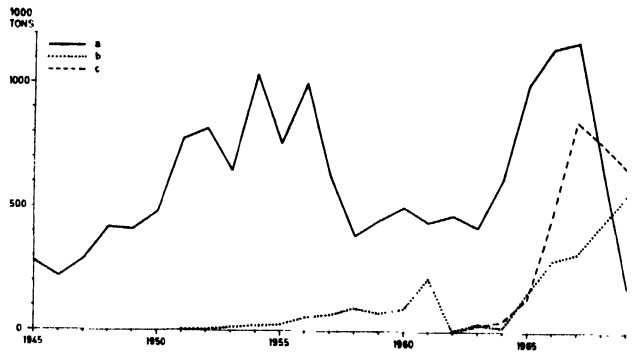

Fig 1. Yield of the Norwegian purse seine fishery 1945–69. (a) herring (b) capelin (c) mackerel

the very beginning of this century, but it was after the last world war that the fishery developed on a large scale. In fig 1 are shown the yearly catches of herring, capelin and mackerel caught by Norwegian seiners since 1945. The curves indicate that the seiners have had two good periods, one culminating in 1956 and one which seems to have culminated in 1967. In between these periods is a poor one (1958–63). The catches before 1964 consisted of herring mainly, whereas recent yield from purse seiners also include considerable quantities of mackerel and capelin.

The increased catches of herring during the first period was due to large investments in seiners equipped with nets operated from two dories. The natural basis for this fishery was the Atlanto-Scandian herring stock exclusively. This stock was very abundant during the period concerned due to several rich year classes (Dragesund, 1970).

In the late 1950's, the strength of the Atlanto-Scandian herring stock was reduced drastically due to failure in recruitment, and Norwegian purse seiners, losing their only source for exploitation, ran into a serious economic crisis. This was met by various measures of government loans and guaranties to convert the boats to other types of fisheries, mostly trawl and longlines. Some attempts to find new fishing grounds for seiners were also made but without success.

This was the situation when the Puretic power block became known in the early 1960's. In the beginning, the new device was met with scepticism, especially with regard to the very large seiners. But every doubt was overthrown when the first boats, equipped with the new gear, started to land large catches of herring from the North Sea in autumn 1964. These grounds which were new for Norwegian seiners soon provided herring and mackerel schools of high catchability and purse seining became again very profitable. By 1968, about 450 vessels were fitted for the new seining technique, representing a new investment of at least 725 million N. kroner (about U.S. $ 100 million) (Mietle 1969).

HISTORICAL REVIEW

According to Thor Iversen (1912), the purse seine technique was introduced in Norwegian waters at the beginning of this century. Norwegians learned the method from the Swedes, who had used purse seines in the Bohuslän fishery since early 1880's. The nets were of the American one-dory type with the fish bag located at one end. This system has later been used in various Norwegian coastal fisheries such as juvenile herring, sprat, cod, coalfish, mackerel and tuna. The boats were relatively small, up to 80 ft long, with pilot house and engine room situated in the stern. Most seiners carried the net on the aft deck, but a few boats operated it from the deck in front of the wheelhouse. The nets varied in size and construction according to the type of fishery. Those used for sprat and juvenile herring measured some 300 × 70 m, whereas the tuna nets could be up to 800 × 90 m.

The deck arrangement and operation of the nets was similar for various fisheries (Hamre 1963). The seiners carried a seine skiff, which was towed when searching for fish. Usually, the seiner was accompanied by a towing boat whose main task was to keep the seiner square with the shot net. When fishing on submerged fish schools, the seiners used bas-boats for directing the shooting of the net. The net was shot to starboard, often with full speed. For hauling in the net, the seiners used a long roller with mechanical drive. Winch power was used for drying up the fish, strapping in the bunt netting sectionally. The fish were brailed aboard except for large fish (tuna), which were hoisted in individually.

The one-dory seiners took part in various fisheries and only changed the nets according to the fish they were searching for. At the end of the 1950's, Norway had some 450 such seiners. The power block became of great importance to this fleet.

The largest catching power lay with big seiners equipped for the two-dory purse seining system. This system is also of American origin and became known to the Norwegian west coast fishermen at the same time as the one-dory net was introduced on the east coast. The first two-dory net was tried by the west coast steamer *Bremnes* under the herring fishery at Iceland during the summer of 1899. The method proved very successful, and purse seining for herring in Icelandic waters during summer became a very important fishery for fishermen from various countries (Iversen 1912). Norwegian steamers equipped for herring seining soon started to operate also in Norwegian waters, first in the winter herring fishery on the west coast, but later they expanded to fish juvenile herring and capelin on the north coast.

The power block

Schmidt (1959) has described the development of the Puretic power block and Jakobsson (1964) how it was adopted by Iceland. Jakobsson states that low catches of herring since 1944 forced the Icelandic fishermen to change from the two-dory, 18-man system, to a one-boat system using only 10–11 men. By the time the power block came, most Icelandic seiners had already changed to one dory. According to Jakobsson, main advantages of the power block were:

(a) saving time and labour in operating nets
(b) enabling fishermen to handle larger and deeper nets, and
(c) securing larger catches without assistance of other crews.

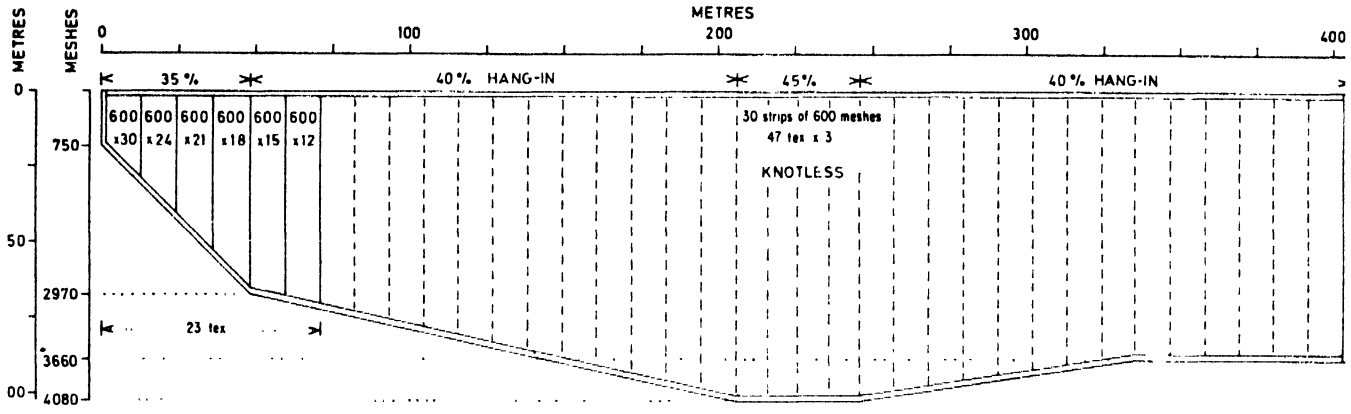

Fig 2. The first Norwegian herring purse seine for power block hauling. The net consisted of 36 vertical strips 600 mesh wide and had a 60 mesh wide selvedge strip of twine 23 tex × 30 around. Framing lines were Terylene. The hang-in along the leadline was about 10 per cent less than for the floatline. tex = 0.1111 × Td

The power block had the same effect for Norwegian small sized seiners. For big seiners, the new system led to a complete change in fishing tactics and it was these large boats which best could utilize the new system. The very serious economic situation due to low catches with traditional gear, gave boat owners no other choice but to try new fishing methods.

The breakthrough for the power block in Norway, resulted from developments in the Icelandic herring fishery. In 1961, Norwegian fishermen went to Iceland to study the technique developed by Mr. Haraldur Agustsson in which the net could be handled from the upper deck aft of the wheelhouse (Jakobsson, 1964). This arrangement met the requirements of the big seiners for carrying the net, because they had no free deck space aft of the bridge. The Icelandic net had also been adjusted to the new hauling technique. The hang-in had been lowered from 60 per cent to 40–45 per cent, which made the net more tight in the hauling direction and the bunt end was cut down in depth so that the fish could be dried up by help of the block only. Details of the first net, which was tried on board a Norwegian herring seiner in 1962, is shown in fig 2.

The new seining technique caused a revolution of the fisheries. In the course of 1963–64, most of the two-dory seiners were equipped with the new gear. The power block system had many advantages and purse seining became suddenly profitable, as new species and grounds could be exploited which previously had not been available to the old seiners. This lead in turn to investment in new and bigger boats, and increased size and efficiency of nets. The building up of the fleet was mainly based on the herring and mackerel stocks in Skagerak and the North Sea, but the new technique has also been of great importance for the herring and capelin fisheries of the north Norwegian coast. This last season (January–April 1970) the purse seiners caught some 900,000 t of capelin, and it is believed that the capelin stock may become the main natural source for large seiners in years to come.

THE VESSELS

As indicated, the Norwegian purse seining fleet may be divided into two groups according to the size of vessels and type of fisheries.

1. Vessels larger than 80 ft catching herring, capelin, mackerel, and polar cod in the open sea and coastal waters
2. Vessels less than 80 ft catching sprat, juvenile herring, coalfish and tuna in coastal and inshore waters.

In addition to the converted two-dory seiners, 130 new vessels of more than 80 ft were equipped with power blocks or similar net hauling devices in the period 1963–68 (Mietle, 1969). Of these, 70 were quite new vessels, 30 were converted whalers and 30 were former trawlers or transport ships. These new seiners were large ships, 120–190 ft with a loading capacity of 350–700 t. But the design of the new boats and the deck arrangement did not differ much from the converted two-dory seiners.

Up to the middle of the 1960's, it was generally believed that vessels smaller than 120 ft would best fit the new technique. Recent trends in development show that this idea has changed completely (Table 1), and even quite new vessels are now lengthened and their decks lifted, so

TABLE 1. NUMBER OF VESSELS ACCORDING TO SIZE AND TOTAL LOADING CAPACITY OF EACH SIZE GROUP IN 1000 T

	Size of vessel in tons	100 to 190	200 to 290	300 to 390	400 to 490	500 to 590	600 to 900	Total
1967	number	103	145	73	27	30	14	392
	capacity	15.5	36.3	25.6	12.2	16.5	10.5	116.4
1969	number	92	121	71	28	38	23	373
	capcity	13.8	30.2	24.9	12.7	20.9	17.3	119.7

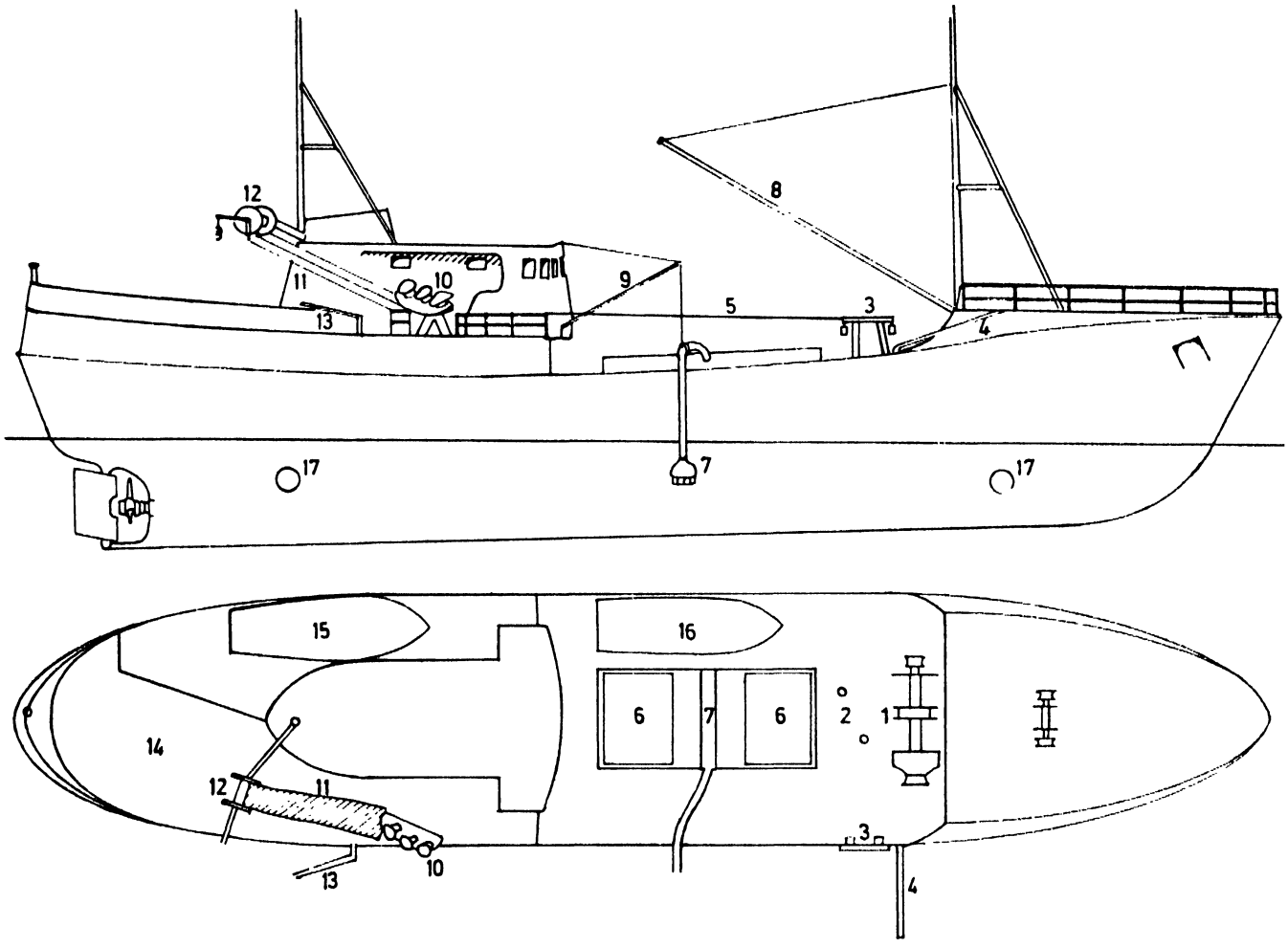

Fig 3. Typical Norwegian purse seine built in 1967. General particulars: LOA: 41.1 m; B: 8.23 m; T: 4.25 m; hold capacity: 400 t; fuel capacity 85 t; freshwater: evaporator and 9 t tank; main engine: 800 hp; auxiliary motors: 35 and 125 hp; speed: 12 kn; accommodation for 14 men

Key: 1. purse winch, 16 tonf; 2. block for purse line; 3. purse gallow; 4. breast boom; 5. ring wire; 6. fish hold; 7. fish pump and dewatering screen; 8. main boom; 9. boom for fish pump; 10. seine winch, 3 and 6 tonf at high and low speed respectively; 11. seine slide; 12. transport drum; 13. ring needle; 14. net bin; 15. towing boat, 22 ft, 100 hp; 16. bas boat, 20 ft, 30 hp; 17. transverse thrust propellers, 100 hp each

that their loading capacity may be increased by up to 30 per cent. The bulk of the catch has been prepared and stored for reduction purposes only. During 1968–69, some 50 seiners were, however, equipped with tanks in which the fish can be stored for human consumption (Mietle, 1969). In the tanks, the fish are kept in refrigerated sea-water—cooling either done by ice or by a combination of ice and cooling machinery. Due to the tendency of failure in availability of herring and mackerel, such tanks are now being installed in most boats.

Figure 3 shows a typical Norwegian purse seiner. The deck arrangement is similar to that described by Jakobsson (1964). The net is carried on the boat deck behind the wheelhouse while pursing and brailing are carried out on main deck. Some of the biggest vessels have two net bins and two nets both ready for shooting (fig 4). Smaller seiners may carry the net on the main deck at the stern. The crew consists of 9–12 men. They are accommodated in single and double cabins, have a large messroom and good sanitary conditions. These, of course, vary with size and age of the ship, but on an average the social standard has been greatly improved in recent years.

In the wheelhouse this standard equipment is found: Decca navigator, radar, radio direction finder, autopilot, radio-telephone, V.H.F. radio-telephone, walkie-talkie sets, sonar and echosounder. In addition, some seiners are equipped with Loran.

Vessels less than 80 ft

Small seiners previously operated their nets from the stern and were the first to adapt power blocks for hauling their nets.

Figure 5 shows a small Norwegian seiner. The net is carried on the main deck behind the wheelhouse and the technique used is similar to that of the large one (fig 3). However, the dimensions and capacities of the equipment are reduced according to the size of the vessel. Standard equipment in the wheelhouse is: Decca navigator, radar, radio direction finder, radio-telephone, walkie-talkie sets, sonar and echosounder.

The crew consists of 7–9 men and they are accommodated in two cabins, one fore and one aft.

Generally, catches of this fleet are for human consumption.

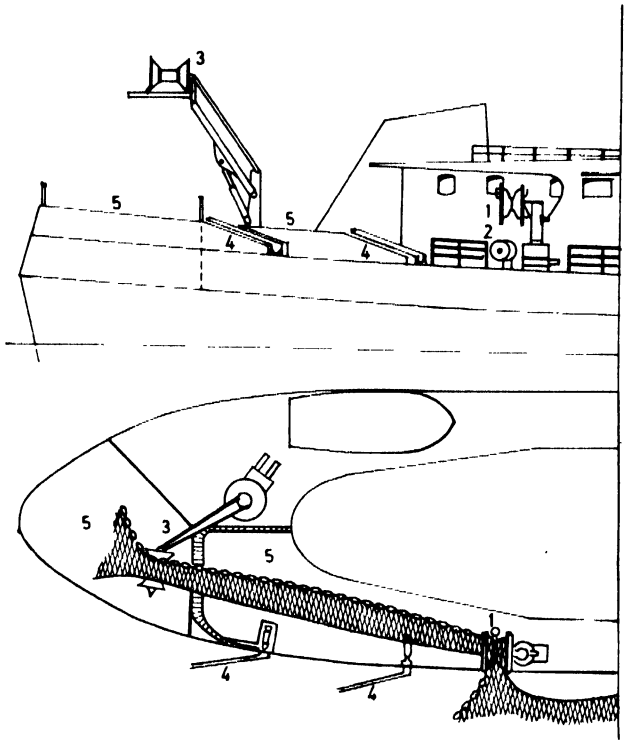

Fig 4. Net hauling arrangement. Key: 1. seine winch; 2. jockey drum; 3. transport drum and crane; 4. ring needles; 5. net bin

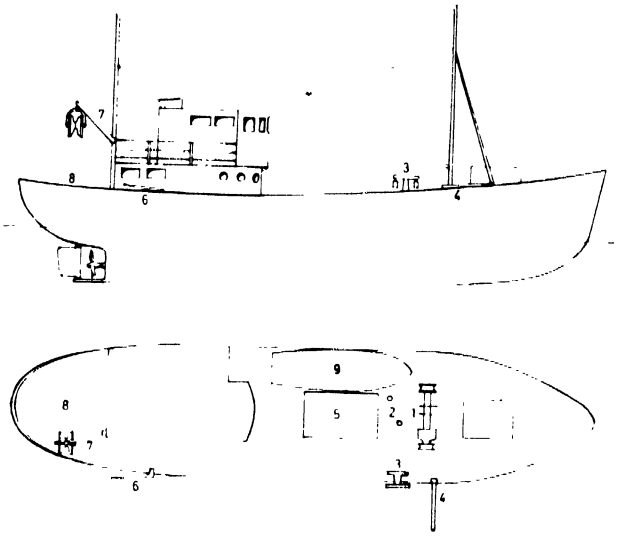

Fig 5. Small Norwegian seiner built in 1962. General particulars: LOA: 21.2 m; B: 5.2 m; T: 2.7 m; hold capacity: 80 t; fuel capacity: 6 t; main engine: 300 hp; auxiliary motor: 10 hp; speed 10 kn; accommodation for 10 men

Key: 1. purse winch, 4 tonf; 2. blocks for purse line; 3. purse gallow; 4. breast boom; 5. fish hold; 6. ring needle; 7. power block; 8. net bin; 9. bas boat, 18 ft, 30 hp.

THE NETS

With regard to tuna nets, reference is made to the paper by Hamre (1963). The net used for coalfish is of a similar construction, but has smaller meshes and much lighter twine in the fish bag. Although now handled by power block, these nets are not specially built for that purpose.

Nets in use for catching mackerel and herring, capelin and sprat are all designed for power block hauling. The shape of the nets and the rigging are similar for the various types, but the size of the net and the dimension of the netting differs according to which species is to be caught. As to details, the nets have no standardized construction, but differ according to the skipper's personal idea of how a net should be made. But a fisherman has a very limited knowledge of the behaviour of his net when shot, and the many but small individual differences in net rigging have probably no operational significance.

The details of net design in the following paragraph, do not refer to particular nets, but are average samples of net specifications collected from four Norwegian factories.

The herring-mackerel net

Details of this net are shown in fig 6. To give an idea of recent development in net design, two sketches of nets are given, one of nets made in 1964–65 (A), and one showing details of nets made in 1969 (B).

Nets made during the conversions period were similar to the Icelandic nets described by Jakobsson (1964), but slightly bigger. Nets made recently have the same shape and rigging, but the size of the gear has increased both in length and depth. But the most marked change occurs in the dimension of twine; the nets now being made are much heavier and stronger. It is natural that the larger seiners built recently require larger and stronger nets, but it is also a fact that most nets made before 1968 were too weak. Particularly for catching mackerel during winter and spring when the fish strongly resist being forced up into cold surface water. Thousands of tons of mackerel have been lost because of light netting used in many nets made during 1964–67.

The netting is hung to the corkline with a hang-in ratio ranging from 35 per cent in the bunt end to some 50 per cent in the centre. The hang-in to the leadline is some 10 per cent less, which makes the leadline correspondingly longer. Plastic floats with a central hole are used instead of cork, and lead pieces fitted to a terylene rope are used as sinkers. The lead weight of the nets, made in 1965, were some 4 kg/m leadline, whereas this weight now is increased some 6 kg/m. The purse rings are made of brass or stainless steel, weighing 4 kg or 6 kg.

Skirts are used in some nets, but dimension and shape may vary. In large nets the skirt is made up to 300 meshes deep, 62.8 mm bar mesh size, twine size 23 tex × 60. The skirt usually covers half of the central portion of the net. At the wing end, the nets are prolonged by a triangular piece of netting to which the edge rope is attached. This netting is made of relatively big meshes (50 mm bar) and thick twine (23 tex × 90), and its function is to obtain a well-balanced pull on floatline and leadline when hauling in the edge rope.

In some of the first nets made for power block hauling, knotless netting was used in central portions of net. Knotted netting is, however, predominating in this type of net.

The sprat and capelin nets

Sketches of these typical nets are shown in fig 7. These are very similar in size and rigging, but the capelin net is some-

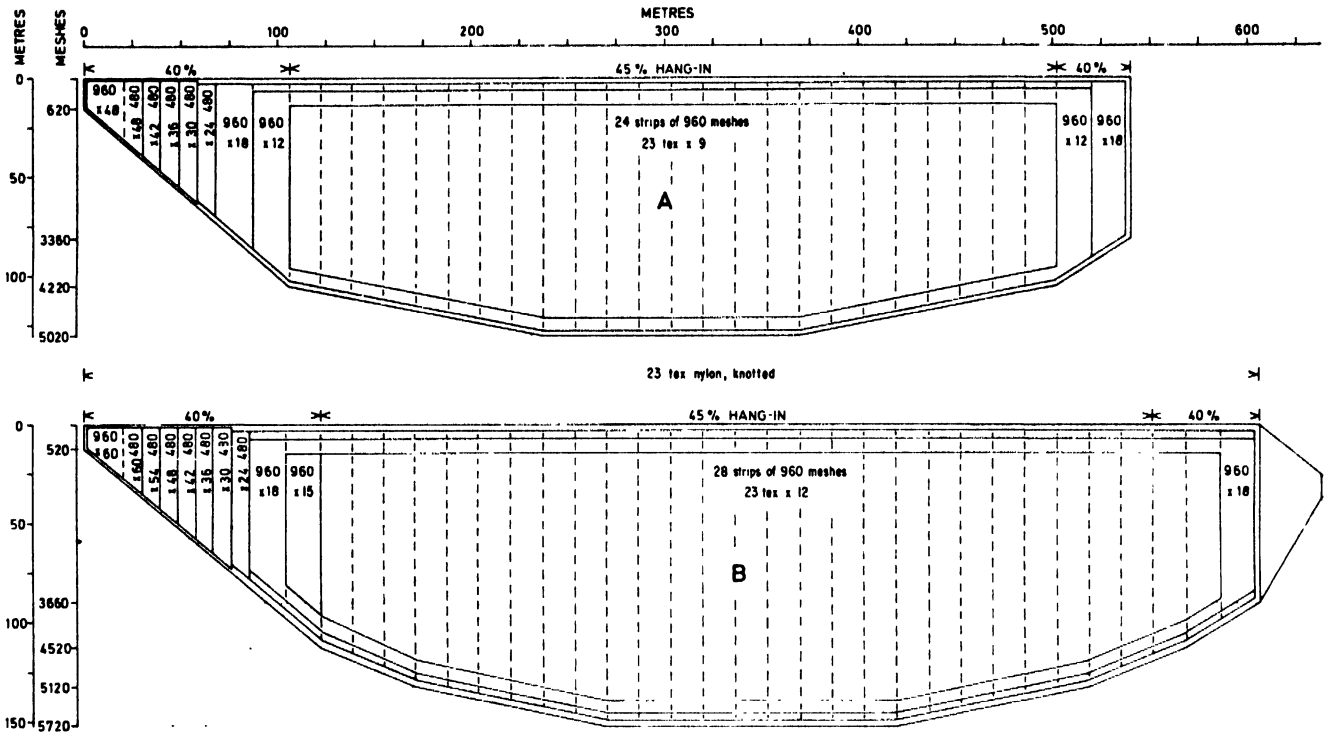

Fig 6. Typical Norwegian herring and mackerel purse seines from 1965 (A) and 1970 (B). The nets are made up of vertical strips of 960 meshes each, and have a 60 mesh wide selvedge strip of twine 23 tex × 72 around, which is gradually reduced in strength inwards to twine 23 tex × 30. The vertical strips are strengthened at the ends as follows: (A) 100 meshes of 23 tex × 18 at the top and 200 meshes of 23 tex 12 at both ends. (B) 100 meshes of 23 tex × 24 and 200 meshes of 23 × 18 at both ends. The mesh size is 15.7 mm bar except for the strips of twine thicker than 23 tex × 24. Here slightly bigger meshes are used (16.5 mm and 17.4 mm bar). All netting is made of knotted nylon twine, 23 tex. tex = 0.1111 × Td

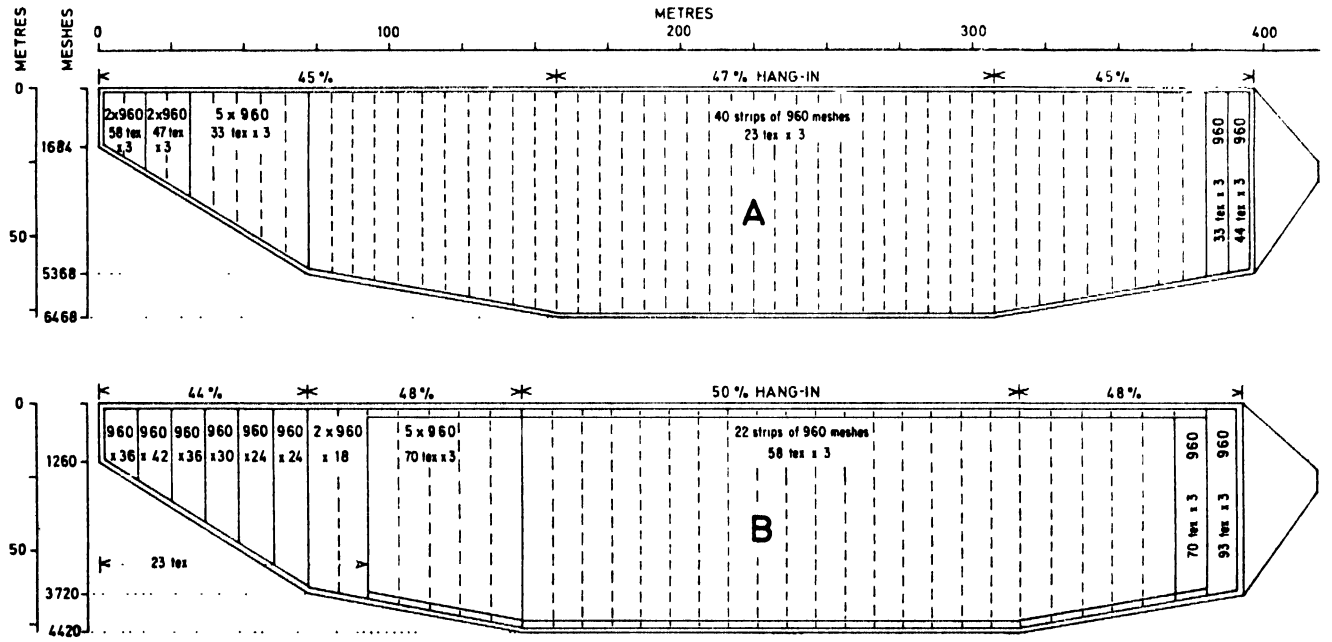

Fig 7. Norwegian sprat (A) and capelin (B) purse seines for power block hauling. The sprat net consists of 51 strips of 960 meshes each and has an 84 mesh wide selvedge strip of twine 93 tex × 3. The whole net is made of knotless netting of 7.4 mm bar. The netting is hung to double Terylene ropes and the hang-in on the leadline is some 10 per cent less than on the corkline. The net has 1,100 kg lead and 32 purse rings of 4 kg each. The capelin net is made up of 37 strips of 960 meshes each, and has a 60 mesh wide selvedge strip of twine 23 tex × 60 decreasing to 23 tex × 24. The vertical strips of the wings are strengthened at both ends by 200 meshes, twine 23 tex × 18. The mesh size is 9.8 mm bar (10.1 mm in the bag). The net is hung similar to the sprat net. It has 1,600 kg lead and 32 purse rings of 4 kg each. tex = 0.1111 × Td

what heavier. The latter is built for use on large seiners and is supposed to handle much bigger catches. The capelin net has not been made bigger according to the increased size of the seiners as was the case for herring and mackerel nets. This is due, most likely, to the fact that capelin fishery often takes place in very shallow water close to the coast. With the exception of the bunt end and selvedges, these nets are normally made of knotless netting.

THE OPERATION

Jakobsson (1964) has described in detail how the Icelandic fishermen handle their nets made for power block hauling. The same system is used by the Norwegians, and slight differences of tactics are no doubt of minor importance. Only some few relevant things which may be specific for Norwegian seiners will be mentioned.

Sonar guided shooting, as described by Jakobsson (1964), is used, but experience has shown that the chances of a successful shot are improved by the use of a bas-boat to locate the top of the school. Bas-boat guided shooting is therefore preferred.

A recent device for keeping the purse line square with the net under the shooting operation is a movable ring needle. This can be moved 1.5 to 2.0 m out from the shipside reducing the risk of getting netting entangled on the purse line.

Specially-made purse winches with capacities up to 20 tons f are now installed on board most modern seiners. They are on the port side opposite the gallow and on a platform so that the wire can run directly to the gallow blocks. To shoot and purse a 600 m net takes about 20 min. When shooting on very deep schools, the pursing operation may be prolonged some minutes to leave time for the net to sink.

Various kinds of hydraulic net hauling systems are used. Three of these are shown in figs 3, 4 and 5. The capacities of these systems vary within a wide range, but large purse seiners use mainly net winches or power blocks with a capacity of 4–6 ton f. The hauling of a 600 m net takes 35–50 min.

During hauling, the vessel is kept square with the net, either by use of a towing boat or thrust propellers. Quite a number of the larger seiners have got thrust propellers of 100–150 hp both fore and aft.

Brailing

Mechanical hauling in of the net is continued until the catch is dry enough for brailing. Brailing is now mostly carried out with fish pumps. If the fish are heavy to dry, pumping is started as soon as possible in order to avoid net-breaking. In the most difficult cases, pump tubes of up to 30 m in length may be used. To prevent the seiner from capsizing when drying-up a heavy catch, a specially-made netholder is mounted to the starboard rail. By this invention, the bag can be untied within a few seconds if necessary for the safety of the vessel.

TRENDS OF FUTURE DEVELOPMENT

Returning to figure 1, the catch curves indicate decreasing herring and mackerel catches, but a yearly improvement in the yield from capelin. In the former species, the curves reflect decreasing stock size due to high exploitation by the purse seine fleet. To prevent further overfishing of these stocks, extensive regulation measures on the Norwegian herring and mackerel fisheries were brought into force from the 1 May this year (1970). The new law prescribes considerably lower catches of these species.

The future prospects of the capelin fishery are, on the other hand, more optimistic, especially after the last season's record catch of some 900,000 t. This general situation in the natural resources has been the guide line for recent fleet development. The boat owners now regard the capelin fishery as the main basis for fishery management at least for the next few years. In this fishery, transport of the catch from the fishing ground to the factories is extraordinarily time consuming. As compensation, the boats receive a price per ton of fish according to distance of transport.

This favours, to a very large extent, the seiners with high loading capacity. The tendency of increasing tonnage by lengthening the hull and lifting the main deck which, discernable last year, is believed to be more pronounced in 1970 (Table 1). As the existing capacity of the purse seine fleet is considered too large for profitable management (Mietle, 1969), a large number of less-profitable seiners has to be removed from the fleet so the fleet may soon be reduced drastically in number, unless other use can be found. This reduction will take place in the group of smaller boats mainly, and the Norwegian purse seine fleet may within some few years consist of a relatively small number of seiners with large loading capacity and highly-specialized in fishing for industrial purposes.

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Anchoita Purse Seining Experiments off Argentina in 1969

T. Gudmundsson, A. Gamberale

Essais de pêche à la seine coulissante de l'anchoita au large de l'Argentine en 1969

D'après les pêches expérimentales et exploratoires effectuées sur l'anchoita au large des côtes d'Argentine en 1969, la migration s'est effectuée dans son ensemble à partir du sud (40°S) en janvier dans la direction du nord-est le long du plateau continental, pour atteindre le secteur le plus septentrional (34° 30'S) à la fin de juillet. Les poissons se sont alors déplacés vers le sud-ouest, le long du plateau, jusqu'à fin août, au moment où débutait un mouvement en direction de la côte. Vers la mi-septembre, les anchoitas atteignaient les eaux peu profondes dans lesquelles ils se maintenaient en se déplaçant lentement vers le sud. En décembre un mouvement vers le large était en cours, et les poissons se trouvaient dispersés depuis 30 milles au large de la côte jusqu'à la bordure du plateau continental. On décrit le comportement groupé et le mouvement vertical des bancs pendant la migration, ainsi que les méthodes et engins mis au point pour une exploitation efficace.

Experimentos de pesca de la anchoita con redes de cerco en aguas de Argentina en 1969

La pesca exploratoria y experimental de la anchoita en aguas argentinas durante 1969 indica que en enero comienza a moverse desde el sur (40°S) en dirección nordeste, a lo largo de la plataforma continental alcanzando la zona más septentrional (34° 30'S) a finales de julio. Posteriormente se mueve hacia el sudoeste a lo largo de la plataforma hasta finales de agosto, mes en que comienza a dirigirse hacia la costa. Para mediados de septiembre ha llegado a las aguas someras en las que permanece durante algún tiempo o se dirige lentamente hacia el sur. En diciembre se observa un movimiento de separación de la costa, y la anchoíta se encuentra diseminada desde unas 30 millas de ésta hasta el borde de la plataforma continental. Se informa sobre las reacciones de l'agregación y movimientos verticales de los cardúmenes durante la migración y de los equipos y métodos empleados en su pesca.

THE UNDP/FAO Fishery Development Project in Argentina has as one of its major objectives the evaluation of the local anchoita stocks and the development of fishing gear and methods for harvesting this resource. In December 1968, FAO provided a 32.6 m (107 ft) exploratory fishing vessel for this purpose, equipped with 680 hp, advanced acoustic instrumentation, a lateral thruster and provisions for both purse seining and trawling.

During 1969, the migrations of anchoita were followed. As the boat also had to make trips for biological and oceanographic purposes, some stages of the annual cycle are not as well covered as desirable, but the general migration pattern and the anchoita's behaviour and reactions towards gear have been determined.

The purse seine available at the start of the field work was 200 × 32 fm of 15 mm stretched mesh and had an average leadline weight of 4 kg per fm. From the first experiments, the net was ineffective under the conditions encountered, due primarily to insufficient depth and slow sinking speed.

This seine was modified by increasing the depth of the middle of the net to 47 fm and giving it a "half moon" shape with 11 fm difference between the centre and the ends and increasing the leadline weight to an average of 8 kg per fm (fig 1). Results were much better, but some problems remained. The bunt held only 40 to 50 tons, and if catches were larger, a part was lost over the corkline. The netting was too weak and the best sets were lost due to tearing. Finally, the mesh size was smaller than necessary, resulting in a slow sinking speed—particularly when the current was strong. Fishing results with this net are shown in Table 1. The experiments provided the minimum design parameters for a suitable anchoita purse seine for this area. Figure 2 shows the design recommended both for coastal and offshore fishing.

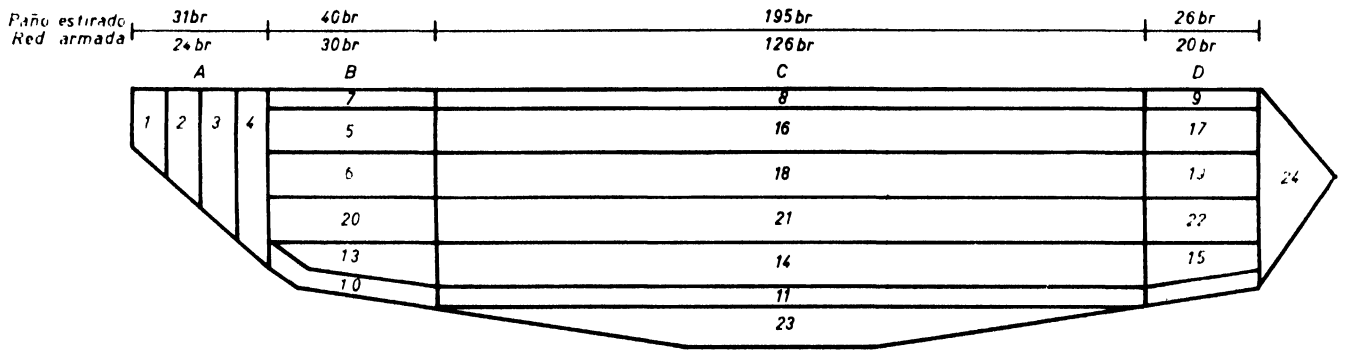

Fig 1. The anchoita purse seine used by the Cruz del Sur

Section	*1– 2*	*210/24*	*SK*	*15*	*mm str. mesh*		*Hanging-in*		*All nylon*
„	*3– 6*	*210/18*	*SK*	*15*	„	„	*Part A 22.6%*		*SK single knot*
„	*7–12*	*210/15*	*SK*	*15*	„	„	*Part B 25.0%*		*KL knotless*
„	*13–15*	*210/9*	*KL*	*20*	„	„	*Part C 35.3%*		
„	*16–22*	*210/6*	*KL*	*15*	„	„	*Part D 23.1%*		
„	*23*	*210/48*	*SK*	*60*	„	„	*Maximum depth 47 fms stretched*		
„	*24*	*210/126*	*SK*	*125*	„	„	*Leadline weight 1,600 kg*		

TABLE 1. FISHING RESULTS WITH MODIFIED PURSE SIENE

Date (1969)	Hour	Catch	Observations
May 9	18:30	-	
" 9	19:20	40 tons	The bunt broke, 20-25 tons were brailed
" 10	18:20	15 tons	Lost by a breakage
" 13	18:20-02:00	20 tons	Five sets. The current, strong
" 14	02:20	35 tons	
" 14	04:40	-	A very extensive rupture of the net
" 19	21:40	20 tons	The catch was good, but lost over the corkline
" 21	21:00	40 tons	Much fish lost over the corkline
" 21	23:30	10 tons	
" 22	05:10	10 tons	
" 22	18:00	20 tons	
July 15	21:30	25 tons	
" 15	23:30	5 tons	A rupture of the bunt
" 18	23:40	-	
" 19	02:00	25 tons	
" 19	03:50	15 tons	
" 19	18:10	5 tons	
" 19	19:30	30 tons	
" 19	21:20	-	A good catch, lost by rupture of the bunt
" 26	00:10	35 tons	
" 26	02:40	10 tons	
" 26	04:20	10 tons	A rupture of the bunt, most of the catch lost
" 26	18:00	20 tons	
" 26	19:50	35 tons	
Aug. 25	20:00	20 tons	The migration towards the coast is beginning and the fish showing more reactions to the boat and the gear.
" 25	21:20	10 tons	
" 25	22:50	15 tons	
Oct. 27	12:20	15 tons	
" 27	13:50	10 tons	
" 27	16:30	40 tons	
" 27	18:00	-	
" 28	08:40	5 tons	
" 28	11:00	5 tons	
" 28	16:30	10 tons	
" 28	17:50		A very big set, estimated over 100 tons, the bunt broke
" 31	10:20	100-150 tons	Lost by a rupture of the bunt
Nov. 3	16:30	-	
" 3	17:20	15 tons	A rupture of the bunt, most of the catch lost
" 4	07:00-16:00	-	6 sets. A NE wind, force 4, made impossible to set towards the current
" 4	16:30	30 tons	The wind was calmer and the set was made to SW
" 5	07:00-16:00	-	Four sets without catches, same reason as above
" 5	16:50	25 tons	
" 7	08:10	10 tons	
" 7	09:30	10 tons	
" 7	11:10	25 tons	Half the catch lost over the corkline
" 7	13:00	-	
" 7	14:20	60 tons	Much fish lost over the corkline

TABLE 2. MIGRATION AND BEHAVIOUR PATTERNS OF ANCHOITA (1969)

Month	Position	Migratory Movement	Behaviour	
			day	night
Jan.	Along 100 fms line between 38°30'-40°+S	Stationary	Compact schools, 10-15 fms below surface, strong reactions	Layer 0-20 fms below surface, varying in thickness and density, good spots for purse seining found the last week of the month
Feb.	No data	No data	As observations made in January and April do coincide, the data for Feb. and March may be assumed to be the same	No data
March	No data	No data		No data
April	Along 100 fms line between 38°-40°S	Stationary, NE movement starting	Compact schools, 10-50 fms below surface, strong reactions	Layer 0-20 fms below surface, varying in thickness and density, good spots for purse seining
May	Along 100 fms line between 36°-39°S	NE along the 100 fms line	Compact schools, 5-15 fms off bottom, out of reach	As above
June	Along 100 fms line between 35°-37° S	As above		
July	Along 100 fms line between 34°30'-36°30'S	Stationary	Compact schools, 5-15 fms off bottom, out of reach	Layer 0-20 fms below surface, varying in thickness and density, good spots for purse seining, sets of 50-100 tons taken
Aug.	Along 100 fms line between 35°30'-38°S	SW, last days Wwards	Compact schools 5-15 fms off bottom, until last week showing a tendency to stay higher	As above
Sept.	Vast area NE-S of M.del Plata, from coast to 100 fms line	Towards the coast	Compact schools in all depths, strong reactions, not captureable. Schools big outside 20 fms, smaller inside	Tiny schools in all depths, compact. Strong reaction, not captureable
Oct.	Along the coast 37°-40°S, between 10-20 fms depth	Stationary or slowly SW along the coast	Compact schools in all depths, slow or no reactions. Most schools from 5-20 tons, but big schools also found. Ideal for purse seining	A very thin layer near bottom, too spread for effective purse seining
Nov.	Along the coast from 20 fms outwards	Slowly first, later more rapidly outside	As above	As above
Dec.	Vast area SW to SE of M.del Plata 30-100 fms depth	Away from the coast, towards the 100 fms line	Tiny, compact schools in all depths, concentrations big enough for effective purse seining not found.	Very thin layer in midwater, no concentrations fit for purse seining

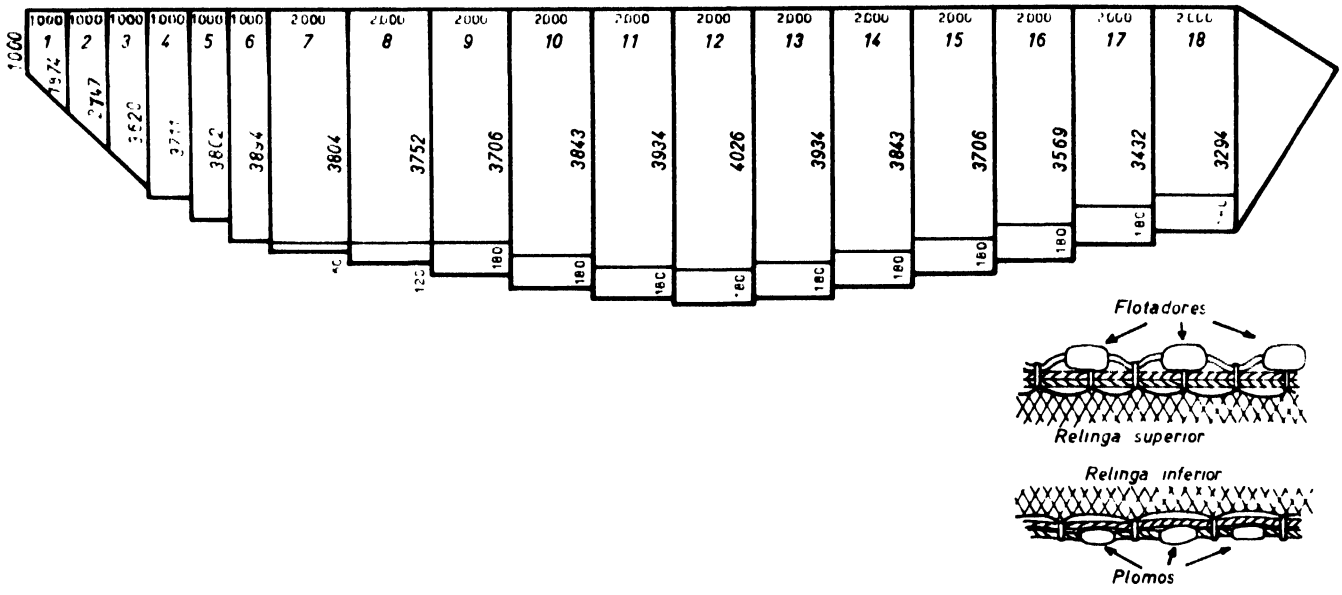

Fig 2. A recommended purse seine construction for anchoita in Argentinian waters

Section 1–3	*210/36*	*25 mm str. mesh*		*Minimum leadline weight*	
„ 4-5	*210/24*	*20 „ „ „*		*Section 1–3*	*4 kg/fm*
„ 6–7	*210/18*	*20 „ „ „*		*„ 4–7*	*6 „ „*
„ 8	*210/12*	*20 „ „ „*		*„ 8–10*	*7 „ „*
„ 9–17	*210/9*	*20 „ „ „*		*„ 11–13*	*8 „ „*
„ 18	*210/12*	*20 „ „ „*		*„ 14–16*	*9 „ „*
Bottom sections	*210/48*	*60 „ „ „*		*„ 17–18*	*10 „ „*

All nylon single knot; hanging in 35% all over; corkline length 214 fms
Depth stretched 50 fms. Selvedge strips: 10 mesh 210/36, 210/24, 210/15

MIGRATION AND BEHAVIOUR PATTERNS OF ANCHOITA

The first survey was made in late January, when the stock was found along the edge of the continental shelf, between 38° 30′ and 40°S. The southern limit was not determined. The schools were compact during the day, stayed 10 to 50 fm (18–90 m) below the surface and showed strong reactions to the approach of the vessel. At sunset, these schools disintegrated and formed a layer of variable density 0 to 20 fm below the surface.

In the first days of April, the fish were still in approximately the same location and behaviour was the same. Since the vessel was not then equipped for purse seining at night, only daylight sets were made. These failed, due to rapid reactions of the fish and the characteristics of the seine.

Beginning in late April, the schools moved northeastwards along the 100 fm contour, reaching the northernmost position in late July, when they extended from about 34° 30′ to 36° 30′S. During this five-month period, the schools rose to the surface at sunset to form a layer between the surface and 20 fm (0–35 m). At dawn, they moved back to the bottom and remained there all day. Figure 3 is an echogram showing the typical daily vertical movement during this period.

In August, a southwestwards movement began and by the end of the month a movement towards the coast had started. Coincidental with this inshore migration was a change in behaviour. Large compact schools were formed at all depths during the day (fig 4), which broke up into many small schools at night. The fish displayed strong flight reactions to the vessel and gear during this period.

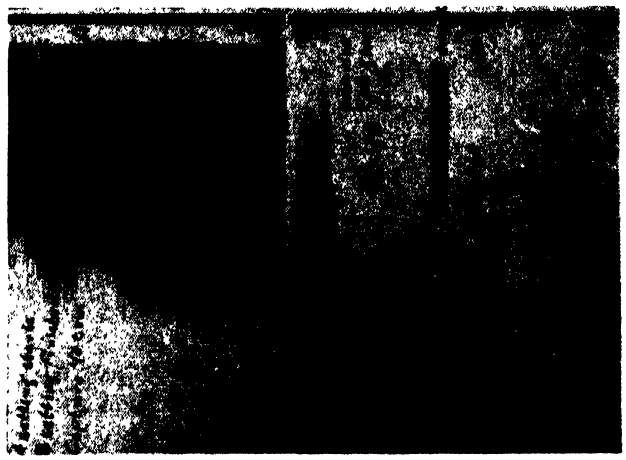

Fig 3. A typical night-time layer during the offshore season (left). After sunrise the fish move to the bottom (right)

In mid-September, the anchoita reached the coast and for the next three weeks formed only small schools in shallow water (8 to 15 fm), seeming to prefer rough bottom. In mid-October, the fish were again observed in compact schools during the day along the coast, SW of Mar del Plata, moving very slowly offshore and staying 5 to 15 fm below the surface. The water depth was 20 to 25 fm. Little or no reaction towards the vessel and gear

Fig 4. A sonar contact with a huge school of anchoita observed in daylight hours during the September inshore migration

was observed. Most of the schools were of 10 to 40 tons, but bigger schools were also found.

In December, the stock was found scattered from about 30 miles off the coast to the edge of the continental shelf south of latitude 39°S. Schools were not concentrated enough for purse seining. Table 2 summarizes the migration and behaviour pattern during 1969.

PURSE SEINING TACTICS DEVISED

Due to the current conditions encountered, the usual purse seining tactics were ineffective. This required development of a method suitable to local conditions. Owing to a constant current flowing northeastwards along the coast, the schools have a constant apparent movement toward the SW. The only way to encircle them is to shoot the net towards the current, disregarding the wind direction, starting with the schools 80° to 90° on the bow. When the circle is complete, the school is well inside it, almost touching the centre of the net. When shooting in other directions, the current takes the net over the school before it has time to sink. Figure 5 shows the tactic applied. Setting a seine in a direction other than towards the wind requires a vessel equipped with a lateral thruster or a powerful helper boat.

Possibilities

Purse seining for anchoita may be assumed to be possible for nine months of the year, divided into two main seasons:

1. Offshore season, February–August. Minimum distance from port 100 miles (April), maximum 220 miles (July). Night fishing.
2. The traditional coastal season, October–November. Distance 20 to 100 miles. Day fishing.

It is evident from the distance to the fishing grounds, and the generally rough weather conditions in the area,

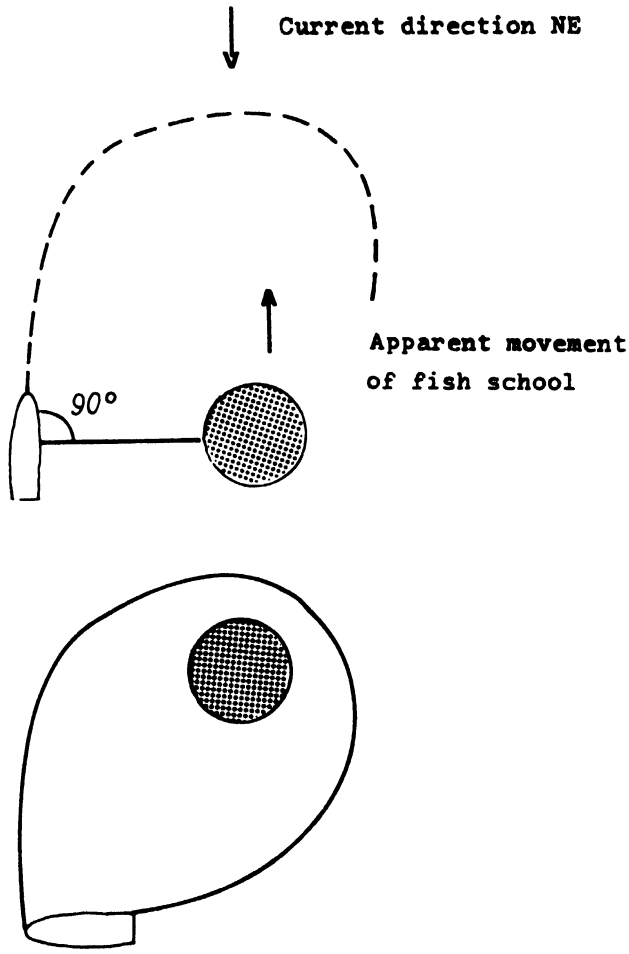

Fig 5 A typical sonar guided shooting during the coastal season. Current towards NE and opposite apparent movement of the school. Top: relative position of vessel and school when shooting starts. Bottom: taking the buoy. The current has carried the centre of the net towards the school

that only big, completely equipped vessels are suitable for offshore fishing. An example is a Scandinavian type purse seiner with a hold capacity of 200 tons or more, equipped with lateral thrusters, a fish pump, a power block, sonar and echo sounders.

For the coastal season, smaller vessels could be used, but since they will need all the equipment mentioned for successful operation, the cost would not be justified for two months fishing per year. About 30 boats of 30 to 120 BRT are presently purse seining for bonito. These boats are fitted with a power block only, so their adaptation to anchoita fishing is almost as expensive as if they had not been purse seining at all.

The anchoita stock is still unexploited, and judging from the sonar and sounder recordings obtained, it is big enough to support a very considerable fishery. The economics will have to be studied to choose an optimum vessel size and further fishing experiments need to be done to obtain an estimate of how much a vessel may be expected to catch during a season. The Project will soon have a purse seine constructed according to the specifications given in fig 2 and results of the experiments with this net will give a more exact idea of the possibilities. Also, it is important to determine whether the migration pattern will be the same as during 1969.

Recent Developments in the Peruvian Anchoveta Fishery

N. Hellevang

Recents progres de la pêche a l'anchoveta au perou

Les quantités débarquées par les pêcheries d'anchoveta du Pérou sont passées de 120.000 tonnes en 1956 à 10 millions de tonnes durrant la campagne 1968/69. Ce bond incroyable est entièrement attribuable à l'accroissement de l'effort de pêche et de l'efficacité de la flotte de pêche. La capacité des seineurs est passée d'environ 30 à 50 tonnes, au chiffre maximal actuel de 350 tonnes. Toutes les embarcations sont désormais équipées de matériel moderne, tel que poulies mécaniques et pompes à poisson, mais les gréements et les treuils pourraient être encore améliorés. Trois filets standard, actuellement en usage, sont décrits en détail. Le plus grand de ces filets mesure 340 × 45 brasses. Aujourd'hui la plus grande partie de la flotte de pêche est équipée d'écho-sounders, mais seulement 10 pour cent des embarcations ont des sonars. Les innombrables populations d'oiseaux de mer sont encore principalement utilisées par les pêcheurs pour détecter le poisson. La pêche à la senne tournante s'effectue sur un seul bateau. Un canot à moteur sert à retenir l'extrémité du filet et la senne tournante durant la calée, ainsi qu'à maintenir le bateau loin du filet durant l'égouttage et le pompage. L'opération d'égouttage se caractérise par deux traits particuliers: le filet est divisé en deux poches pour les prises importantes et un tangou spécial sert à maintenir la ralingue liégée hors de l'eau durant le pompage. Un bref résumé du cycle biologique naturel de l'anchoveta permet d'expliquer les règlements en matière de pêche (par exemple, contigents saisonniers) imposés par le Gouvernment. Ces règlements sont fondés sur des recommandations concernant le rendement maximal possible formulées par des spécialistes péruviens en matière de pêches, travaillant en collaboration avec la FAO. A l'occasion de la récente réunion d'un groupe d'experts internationaux, le chiffre de 9,5 millions de tonnes a été recommandé, ce qui sous-entend que le stock est pleinement exploité à l'heure actuelle

Progresos recientes en la pesqueria de la anchoveta en el Peru

Los desembarques de anchoveta aumentaron en el Perú de 120.000 toneladas en 1956 a 10 millones de toneladas en la temporada de 1968/69. Este enorme incremento hay que atribuirlo en su totalidad al mayor esfuerzo pesquero y a la mayor eficacia de la flota. Los barcos de ésta han aumentado de tamano pasando de 30 a 50 toneladas, hasta un màximo de 350 en la actualidad. En todos los barcos hay ahora instalado equipo moderno tal como dispositivos fpara el halado mecánico de las redes y para bombas para le descarga del pescado, pero podrían mejorarse los aparejos de las poleas y las maquinillas. Se describen con detalle tres tipos de redes que se emplean en la actualidad. La mayor de ellas es de 340 × 45 brazas. Actualmente, casi toda la flota está equipada con ecosondas, pero solamente un 10 por ciento lleva sonar. Para localizar peces, los pescadores se valen, sobre todo, de la enorme población de aves marinas. La técnica pesquera que siguen es la de hacer el cerco desde un bote. Para sostener el extremo de la red y el cable de la jareta durante el lance se emplea un bote auxiliar de motor que sirve también para mantener la embarcación alejada de la red mientras se salabardea y se bombea el pescado. Dos rasgos únicos de la operación del salabardeo son que la red se divide en sacos separados para las grandes capturas y que se usa una botavara especial para mantener en alto la línea de corchos durante el bombeo del pescado. Se incluye un breve resumen del ciclo vital de la anchoveta para explicar los procedimientos de regulación de la pesquería (por ejemplo, cupo por temporada) impuestos por el gobierno. Esto se basa en las recomendaciones de los investigadores pesqueros peruanos, que trabajan en unión de la FAO, para obtener el rendimiento máximo sostenible. En una reunión reciente de un grupo de expertos internacionales se recomendó la cantidad de 9,5 millones de toneladas, lo que supone que la población se está explotando en su totalidad.

PRIOR to the early 1950's, when commercial exploitation began, it was well known that a large population of anchoveta (*Engraulis ringens*) existed along the coasts of Peru and northern Chile. Earlier commercial utilization of this stock was indirect, in the form of guano deposited on the offshore islands by the millions of local sea birds whose main diet is the anchoveta.

In 1956, landings in Peru had reached 120,000 tons. By 1964, landings had neared 9 million tons. In 1965, the fishery suffered a decline to 7.2 million tons, but recovered in 1966. Finally, a record 10.2 million tons was landed during the 1968/69 season.

This rapid development was accompanied by numerous problems. Lack of planning, basic knowledge, and experience led to many unfortunate investments. Poor maintenance and lack of repair caused many factories to close down. When landings declined drastically in certain ports, whole factories were forced to move to ports with more consistent landings. Many vessels were built on the streets of Callao by people inexperienced in boat construction. Poor construction and maintenance plagued many vessels.

Today there are over 120 fish meal factories operating from Ilo, on the Chilena border, to Chicama in the north. The major centres of production are Pisco, Callao and Chimbote. The fleet consists of more than 1,400 vessels.

Scientific monitoring of the fishery began in 1960 with the formation of the Marine Resources Research Institute, under guidance of FAO. In 1964, the Peruvian Sea Institute (Instituto del Mar del Peru) was created, and is carrying the work forward. Good cooperation has been received from the fishing industry, under the National Fishery Society (Sociedad Nacional de Pesqueria). The Government has generally accepted the advice of these organizations, and since 1965, has been limiting catches by imposing seasonal quotas.

FISHERY CONDITIONS

The anchoveta population covers the area from Antofagasta, Chile to Punta Aguja, Peru, approximately 1,200 n mi and seaward from the beach to 70 n mi. The fish are rarely found below 30 m. These boundaries are very flexible, however, as the fish respond to changes in ambiental conditions, and food availability. There is ample evidence that its habitat is roughly bounded by the temperature range of 14° to 20°C, and an oxygen minimum of 0.25 ml/l.

In general, the anchoveta spawn throughout the year, but with a peak in winter, July through September. During this period, the fish become very dispersed over the fishery area, and are least available to the fleet. This has been observed from low, winter catch-per-unit-effort figures during the pre-regulatory period. Winter closures, generally June through August, protect the adult fish

during spawning. Also, by June the season catch quota has normally been reached, and the fishery would be closed at any rate. The fishing season, for regulatory and statistical purposes, is considered as from the end of one winter closure until the beginning of the next.

Recruit fish from the winter spawning begin to appear in landings in late December or early January. A high percentage of these small fish in the catches leads to lower yields of both oil and meal. In some years, the entire fishery is closed at some time during the summer months, January through March. This year for the first time, only ports with high percentages of recruits in their landings were closed. During the summer months, the fish are more concentrated near the coast, and are most available.

Time for these closures is not rigidly set, but they are imposed when conditions warrant them. This is perhaps the best method, considering possible shifts in average size, abundance, and availability from year to year. As an example, at time of writing, the Government decreed a closed season from 16 February to 15 March to reduce fishing effort.

Sea conditions are very favourable as wind velocity rarely exceeds 5–6 (Beaufort). A low, heavy overcast hangs over the sea for approximately 9 months of the year, the exception being the southern hemisphere summer. Rich upwelling along the coast, and the subsequent growth of plankton, causes the water to be opaque, with colours ranging from green to reddish brown. An enormous but highly variable population of sea birds competes for the anchoveta, yet at the same time provides a service by locating the fish. The bird population during 1968/69 fishing season was estimated at 5.4 million, and their consumption of anchoveta at 0.85 million metric tons.

FISHING VESSELS

Development of anchoveta fishing vessels has kept pace with the fishery. Initially, 30 to 50 ton (metric) capacity vessels were used. Today, there are four tonnage-capacity classes of boats in use. Size and tonnage vary within each class, but in general are as follows: The smallest are 100 to 140 ton vessels with a length of 65 ft, and a 24 ft beam. Next are 180 ton vessels, 85 ft long with a 25 ft beam. These are followed by a small class of 250 ton vessels of 99 ft. The largest seiners now carry more than 300 tons and are 115 ft long with a 26 ft beam. The greatest percentage of the fleet falls within the smallest class. Approximate crew requirements are from 12 to 15 men. A modern 350 ton vessel, fully loaded, is shown in fig 1.

Vessel construction, early in the fishery, was almost completely of wood. Today, the fleet consists of roughly 63 per cent steel vessels. Statistics show that catch rates of wooden vessels decrease with time more rapidly than those of steel vessels, but this is mainly a matter of maintenance. At present, there is no new construction of vessels less than 270 tons. An approximate cost of a steel vessel of this size would be US$250,000. A 350 ton steel vessel would cost roughly US$325,000 whereas a wooden vessel of this same size could be built for approximately one-third less. A local company is now building 350 ton fibreglass vessels at a price competitive with wooden vessels of same size. At present, one of these vessels is in service, and five are under construction.

Fig 1. A new 350-ton vessel, fully loaded

The Peruvian fishery is a day-fishery, and the vessels are unloaded each day to reduce spoilage. Since there are extremely few cases where 350 ton boats are fully loaded in one day, it appears hardly practical for companies to acquire vessels of a higher capacity.

To a European fisherman, these vessels look rather unseaworthy and it would be difficult to convince them that they carry as much fish as they do. With the sea conditions prevalent off Peru, however, the seiners are extremely serviceable. They are manoeuvrable and, with engines up to 850 hp, some of the larger seiners can run at 12 kn. The smaller vessels have at least 250 hp, and the minimum speed in the fleet is probably 9 kn. All vessels are now equipped with power blocks, and these are fitted to the boom. When the catch is very heavy, the power blocks cannot lift the net, and it is necessary to use a line from the deck winch and straps to assist in retrieval. This process could be simplified by use of deck-mounted power blocks, but there are none in the fleet. Fish pumps are also standard equipment. The rigging, however, is not very good. Few vessels, for example, have

Fig 2. A typical double-capstan winch aboard a new seiner. Over 95 per cent of the fleet uses this type of winch The purse-davit can be lowered to the deck after the net has been pursed

a good purse winch; almost all are equipped with only a simple, double-capstan winch (fig 2). None of the vessels have bow or stern thrusters. They have only one large fish hold which is compartmented for load distribution, and is not refrigerated. A typical deck outlay is shown in fig 8. The net skiff is carried on an angled stern ramp.

Experience with the larger vessels has been mixed, some companies having had problems due to increased size. As these vessels evolved, little consideration was given to their different movement in the sea relative to smaller seiners. Equipped with the same deck gear as smaller vessels, much rigging and many winches and booms have been damaged during fishing operations.

Another problem has been that of unloading. The coast of Peru offers few natural harbours, and most factories are located on an open coast with little or no lee. Unloading usually takes place from floats, which in many cases are too poorly anchored to accommodate the larger vessels.

There are no electronic navigation aids in Peru. The general proximity of fish to the shore, plus their enormous abundance, necessitates only the most rudimentary dead reckoning. Some of the newer vessels are radar-equipped.

THE PURSE SEINE

Experience gained has resulted in significant changes in the nets used in this fishery. Each individual captain or net-maker has his own personal ideas as to how nets should be made, depending on various factors such as size of vessel. Paramount factors in net design, however,

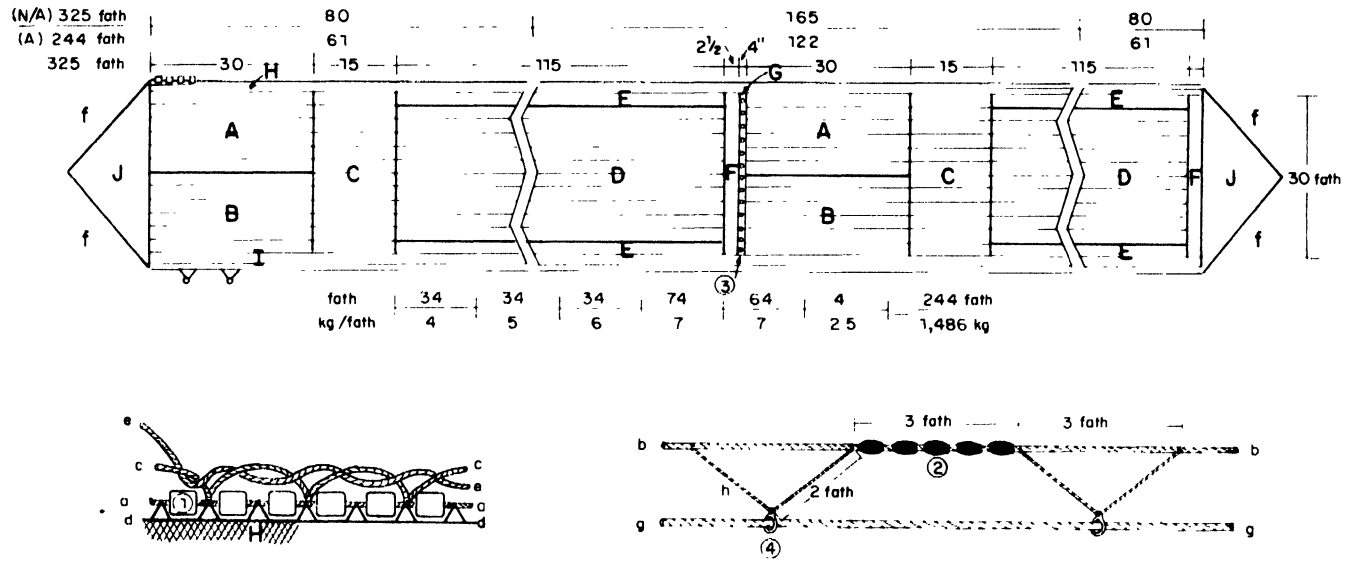

Fig 3. Anchoveta purse seine. Designed for fishing boats from 100 to 200 tons capacity

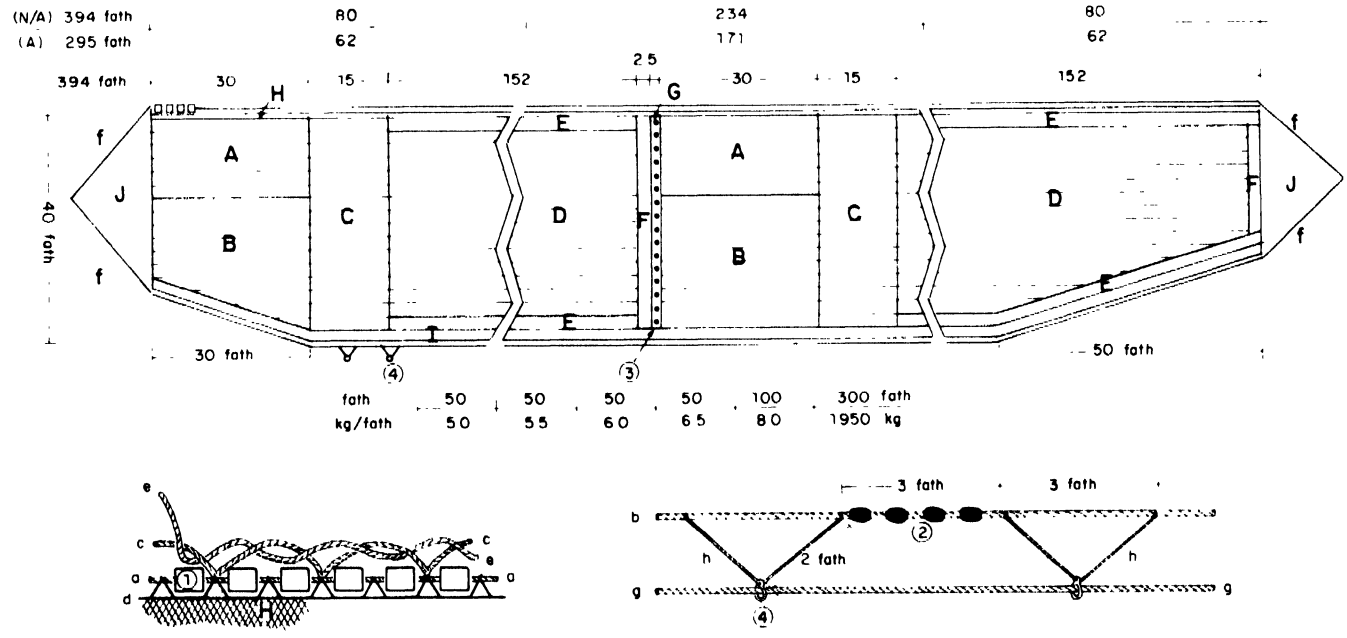

Fig 4. Anchoveta purse seine. Designed for fishing boats from 200 to 300 tons capacity

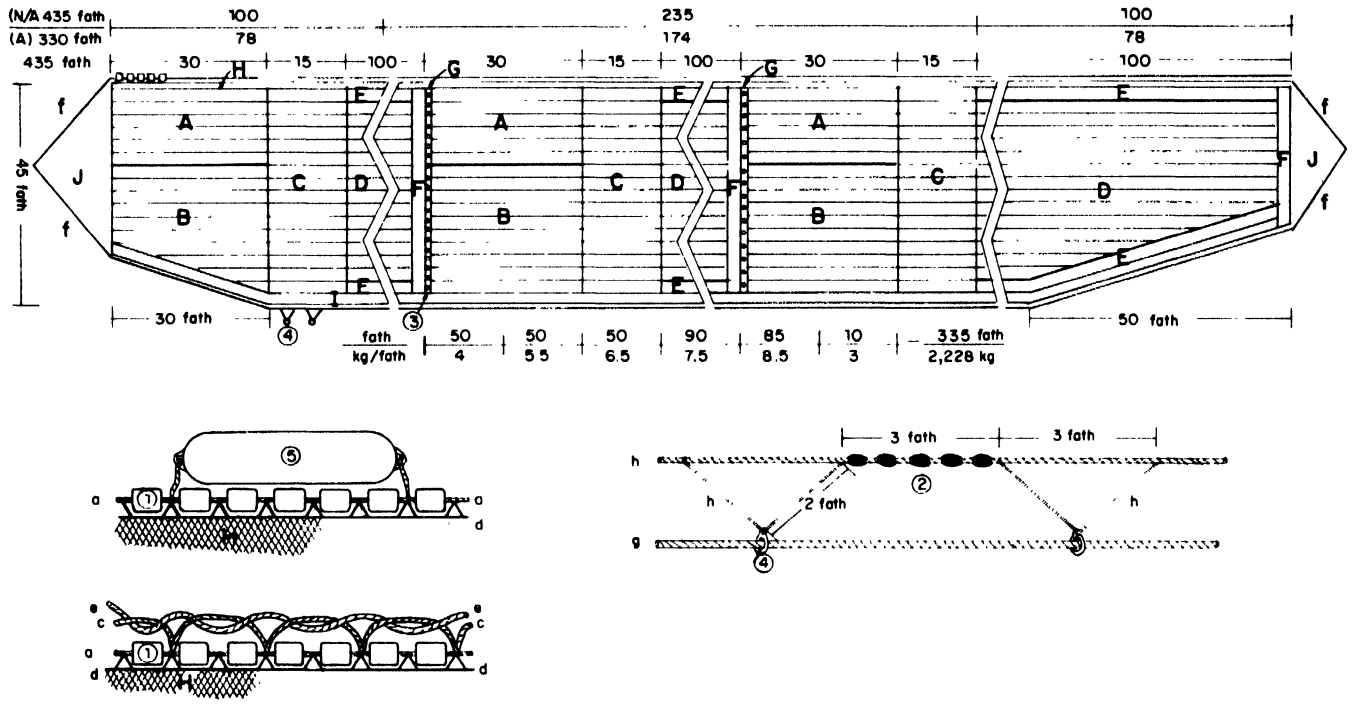

Fig 5. Anchoveta purse seine. Designed for fishing boats of more than 300 tons capacity

have been the behaviour and size of the anchoveta. This has resulted in a degree of standardization of net design. The fact that the fish are small, from 7 to 17 cm in length, has dictated a small mesh size of ½ inch stretched mesh. The nets are quite long relative to their depth. Although a relatively fast swimmer, the anchoveta seldom dives, so the nets do not have to be too deep. If ringed, the anchoveta is normally caught.

There are three basic types of nets presently in use, and their dimensions depend on the size of the vessel (fig 3, 4, 5). They are made with two or three bunts, or bags, since it is almost impossible to dry-up more than 150 tons in one bunt. Rings on the net are provided for splitting it into separate bags. The specifications for each net are given in Tables 1, 2 and 3.

In the early years of the fishery, the nets were hung in 10 per cent, but now 25 to 30 per cent is common (125–130 fm of stretched netting per 100 fm of cork line). Almost 90 per cent of the nets were hung on nylon cork lines, and as a result, lost half of the hanging in a short time. Currently, the cork and lead lines on some nets are made of terylene which is a more favourable material for resisting stretch.

FISHERY TECHNIQUES AND TACTICS

Fish finding has not changed much since the early years. Long distance observation of feeding birds is still the most characteristic method. Acoustical equipment began to appear in the fleet in 1962. Before 1964, there were only echo sounders, but by the end of that year, sonars were installed on five vessels. Although approximately 10 per cent of the present fleet is equipped with both, these instruments have not been extensively used for fish location. Aerial spotting has been successful in Chile, but the opaque water conditions in Peru have made this method impractical here.

Once the fish have been found, it is important to determine direction and speed of school movement. Under normal conditions of opaque water, the vessel is brought up to the school and special crew members look into the water to make this determination. It is possible to do this in 90 per cent of typical operations. At this time, also, the size and depth of the school is checked with the echo sounder. In the dirty water, the fish are not bothered by the proximity of the vessel and will seldom increase speed or change direction. When the water is clear, however, the fish become nervous and it is impossible to approach them without causing changes. At this time, the better captains on sonar-equipped vessels have an advantage since they can use their equipment to determine school movement without closing range with the school. The sonar is also useful for determining the largest school in a multi-school concentration. Proficiency with sonars undoubtedly will increase as more units are brought into the fleet and increased fleet efficiency creates stronger competition for schools.

Catching the anchoveta in opaque water is a relatively simple operation. Once speed and direction are established, it is necessary only to pull ahead of the school, leave enough time to set the net before the school arrives, then close it after the fish have entered. From practical experience the captains know that the fish travel at 2 to 3 kn in dirty water, and seldom change direction. Even if they run into the net, they will not reverse course and try to escape. In clear water their behaviour is not predictable, and their swimming speed may increase to

TABLE 1. NET SPECIFICATIONS FOR 100–200 TON VESSEL

Name of gear:	*Purse seine*	Fishing conditions:	*Pelagic*
Type:	*Anchoveta purse seine*	Depth:	*Down to 40 fm*
Country:	*Peru*	Vessel:	*Purse seiners*
Reference:	*N. Hellevang*	Length:	*60 ~ 80 feet*
Main species:	*Anchoveta*	Capacity:	*100 ~ 200 tons*
		Power:	*200 ~ 400 hp*
		Crew:	*12*

WEBBINGS	A	B	C	D	E	F	G	H	I	J
Material	Nylon	→	→	→	→	→	→	→	→	→
Type of knot	~~X~~	→	→	→	→	→	→	→	→	→
Preservation	Dyed									
Colour	Brown									
Number of twine (Td.)	210/21	210/15	→	210/9	210/15	→	210/180	→	→	210/140
Break resistence (kg)										
Mesh size (inches)	1/2	→	→	→	→	→	2	2	3½	5
Top edge (fathoms)	30	30	15	115	115	2.5	4 meshes	325	325	10
Bottom edge (fathoms)	30	30	15	115	115	2.5	4 meshes	325	325	10
Height (fathoms)	15	15	30	25	2.5	30	30	4 mesh.	30 mesh	20
Reduction inside / outside										
Hanging	80/61			165/123			80/61	= 325/244		

ROPES	a	b	c	d	e	f	g	h			
Material	Teryl.										
Preservation											
Diameter (inches)	1	3/4	5/8	3/16	3/4	1	1⅛	5/8			
Circumference (inches)											
Break resistance (tons)											
Construction											
Twist direction	Z	→	→	→	→	→	→	→			
Length (fathoms)	244	244	60	1,800	40	60	450	160			

FLOATS, LEADS	1	2	3	4	5
	Floats	Leads	Rings	Purse Rings	Plastic Buoys
Number	2,928	2,972	20	40	30
Material	Syntetic	Lead	Brass	Stainles Steel	Plastic
Shape	Cyl.				Cyl.
Diameter (inches)	6				15
Length (inches)	4				70
Width (inches)					
Weight in air (kg)		1,486		3	

TABLE 2. NET SPECIFICATION FOR 200–300 TON VESSELS

Name of gear:	*Purse seine*	Fishing conditions:	*Pelagic*
Type:	*Anchoveta purse seine*	Depth:	*Down to 40 fm*
Country:	*Peru*	Vessel:	*Purse seiners*
Reference:	*N. Hellevang*	Length:	*85 ~ 110 feet*
Main species:	*Anchoveta*	Capacity:	*200 ~ 300 tons*
		Power:	*350 ~ 600 hp*
		Crew:	*12*

WEBBINGS	A	B	C	D	E	F	G	H	I	J
Material	Nylon	→	→	→	→	→	→	→	→	→
Type of knot	⊗	→	→	→	→	→	→	→	→	→
Preservation	Dyed									
Colour	Brown									
Number of twine (Td.)	210/21	210/15	→	210/9	210/15	→	210/180	→	→	210/240
Break resistance (kg)										
Mesh size (inches)	1/2	→	→	→	→	→	2	→	3 1/2	5
Top edge (fathoms)	30	30	15	152	152	2.5	4 meshes	394	394	10
Bottom edge (fathoms)	30	30	15	152	152	2.5	4 meshes	394	394	10
Height (fathoms)	15	25	40	35	2.5	40	40	4 meshes	30 meshes	20
Reduction inside / outside										
Hanging (fathoms)	80 / 62	234 / 171				80 / 62	= 394 / 295			

ROPES	a	b	c	d	e	f	g	h	i		
Material	Teryl.	Teryl.	Nylon	Nylon	Teryl.	Nylon	Cable	Nylon	Teryl.		
Preservation	Dyed										
Diameter (inches)	1	3/4	5/8	3/16	3/4	1	5/8	5/8	3/4		
Circumference (inches)											
Break resistance (tons)											
Construction											
Twist direction											
Length (fathoms)	295	300	60	1,100	40	60	485	200	50		

FLOATS, LEADS	1	2	3	4	5
	Floats	Leads	Rings	Purse Rings	Plastic Buoys
Number	3,540	3,900	25	48	30
Material	Syntetic	Lead	Brass	Stainless Steel	Syntetic.
Shape	Cyl	Oval			Cyl.
Diameter (inches)	6				15
Length (inches)	4				70
Width (inches)					
Weight in air (kg)		1,950		30	

TABLE 3. NET SPECIFICATIONS FOR VESSELS OVER 300 TONS

Name of gear:	*Purse seine*	Fishing conditions:	*Pelagic*
Type:	*Anchoveta purse seine*	Depth:	*Down to 40 fm*
Country:	*Peru*	Vessel:	*Purse seiners*
Reference:	*N. Hellevang*	Length:	*110 ~ 120 feet*
Main species:	*Anchoveta*	Capacity:	*More than 300 tons*
		Power:	*600–850 hp*
		Crew:	*15*

WEBBINGS	A	B	C	D	E	F	G	H	I	J
Material	Nylon	→	→	→	→	→	→	→	→	→
Type of knot	⊗	→	→	→	→	→	→	→	→	→
Preservation	Dyed									
Colour	Brown									
Number of twine (Td.)	210/21	210/15	→	210/9	210/15	→	210/180	→	→	210/240
Break resistance (kg)										
Mesh size (inches)	1/2	→	→	→	→	→	2	2	3½	5
Top edge (fathoms)	30	30	15	100	100	2.5	4 meshes	435	435	10
Bottom edge (fathoms)	30	30	15	100	100	2.5	4 meshes	435	435	10
Height (fathoms)	15	25	45	40	2.5	45	45	4 meshes	30 meshes	25
Reduction (inside / outside)										
Hanging (fathoms)	100/78			235/174		100/78	= 435/330			

ROPES	a	b	c	d	e	f	g	h			
Material	Teryl	→	Nylon	→	Teryl.	Nylon	Wire	Nylon			
Preservation											
Diameter (inches)	1	3/4	5/8	3/16	3/4	1	3/4	5/8			
Circumference (inches)											
Break resistance (tons)											
Construction											
Twist direction	Z	→	→	→	→	→	→	→			
Length (fathoms)	330	350	60	2,000	40	30	500	216			

FLOATS, LEADS	1	2	3	4	5
	Floats	Leads	Rings	Purse Rings	Plastic Buoys
Number	3,960	4,456	20	54	30
Material	Plastic	Lead	Brass	Stainless Steel	Plastic
Shape	Cyl.				
Diameter (inches)	6				15
Length (inches)	4				70
Width (inches)					
Weight in air (kg)		2,228		3 each	

Fig 6. The net skiff in position, just prior to shooting the gear

5 to 6 kn. Clear water conditions along the coast, however, are the exception.

On occasions, the fish do not concentrate and form schools. The only indication of their presence is bird activity; no significant registration appears on either sonar or echo sounders. If their direction can be determined by watching individual fish in the water, and the net set ahead of the fish and left open for some time, it is not uncommon to catch 50 tons or more. This emphasizes the dependence on birds in the fishery, and the tendency to downgrade some of the acoustic methods.

Shooting the gear is similar to any conventional one-boat seine operation. A power skiff is used to hold the net end and purse line during the set. Figure 6 shows the net skiff in position, just before the gear is shot. The primary difference in Peru is the method of drying-up the catch. Anchoveta become very heavy in the net, and it is necessary to cut the catch into separate bags of 150 tons or less. When drying-up these large catches, a three-

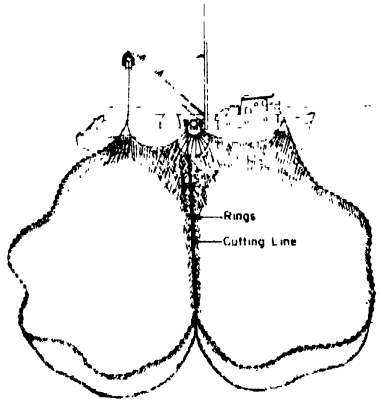

Fig 7. The purse seine being cut into two parts, as is done when the catch is large. The cutting line passes through rings sewn on the net, and is tied to the leadline. To cut the net, the line is taken to the capstan and drawn up tight

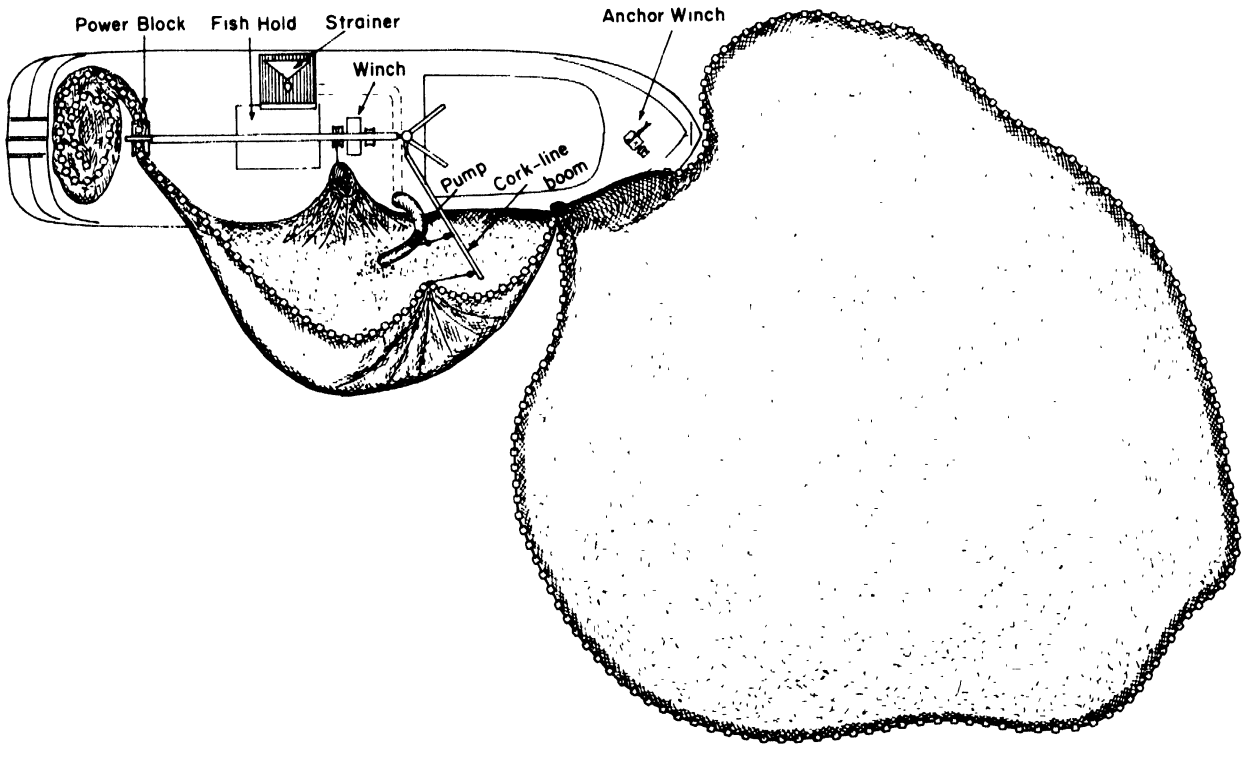

Fig 8. A typical operation with two-bag net. The net has been cut, the first bag dried-up, and pumping is taking place. The other half of the net is left open so the remainder of the catch can swim freely. The deck layout of power block, winch, pump, strainer, hold and corkline boom is typical of Peruvian seiners

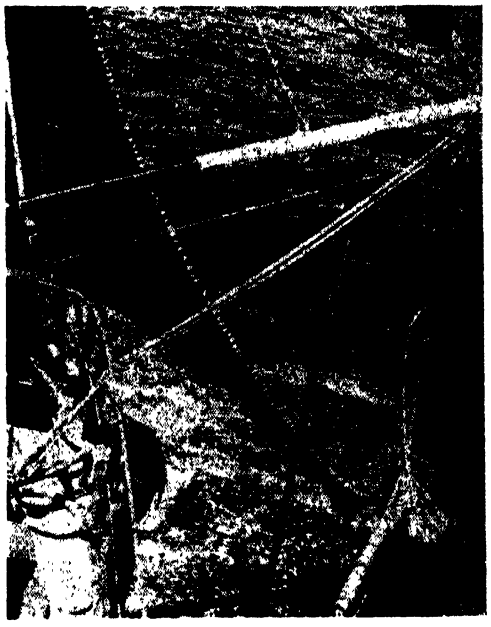

Fig 9. Pumping out the dried-up net. The corkline is held up by the special boom during this operation

sheave block must be used due to the extreme weight. One reason for this is the small mesh used in the net, which does not permit efficient drainage of water as the net area is decreased. Figure 7 illustrates how the net is cut. Figure 8 illustrates a pumping operation in progress on a net which has been cut. One bag has been fully dried, while the other half of the net is left open with the remainder of the catch. This permits the remaining fish to swim freely. When the first bag is empty, the second will be hauled in, dried, and pumped in the same manner.

Vessels in the Peruvian fishery are equipped with an additional boom to keep the cork line up during the drying-up process (fig 9). The net skiff is used to support the cork line.

FUTURE PROSPECTS

The future of the fishery will depend to a great extent on the continuing assessment of stock size by regulating agencies of the Peruvian Government, working in conjunction with FAO. At a recent meeting, a panel of international experts recommended 9.5 million tons as the present sustainable yield. This means that the stock is presently being fully utilized. Changes in the industry will, therefore, be programmed toward increased harvesting efficiency.

With the present trend to build larger vessels, it seems reasonable to assume that the fleet will decrease in number of vessels. This should continue until an equilibrium is reached between the allowable quota and fleet efficiency. More emphasis will be placed on electronic equipment. As more sonars become available to the captains, they will certainly adapt them to the fishery conditions, and become more dependent on them. At any rate, the present impetus to update vessels, gear, and techniques will continue, and should bring this industry to a high degree of efficiency.

DISCUSSION

DESCRIPTION OF SOME MAJOR FISHERIES

Kristjonsson (FAO) Rapporteur: There are 19 papers to be reviewed in this session and to keep order in the wide subject matter I will deal with them as follows. After a brief review of the global situation we come to: Mediterranean and West African sardine fishing; Japanese mackerel and horse mackerel purse seining; tuna purse seining in the U.S.A., Japan and West Africa; purse seining in Peru and Argentina; Iceland, Norway and U.S.S.R.; and finally combination fishing.

A little over one third of the world's catch today is taken by purse seines, and since the potential catch of schooling pelagic fish is estimated at 50 to 60 million tons per year, there are opportunities all over the world for expansion of purse seining, including the North Atlantic, both for traditional and neglected species. From what we know now, new purse seining fisheries could develop, perhaps exceeding a million tons per year for each of several species, such as anchovy off the southern Californian coast and Mexico which at present are protected by sport fishermen. Another example is the Argentinian anchovy which FAO is sampling. A third opportunity is in the Arabian sea with its sardinella and Indian mackerel. It is estimated by the World Indicative Plan in FAO that fish consumption should rise to 74 million tons by 1975 and 107 million tons by 1985. These are conservative estimates in view of the world population growth which is rising so alarmingly that no prognosis beyond 1990 make sense unless there is a drastic change in the pattern of population dynamics of mankind.

We are not interested in history at this congress except inasmuch as it helps understanding of the development of gear and methods. Perhaps it is true to say that relatively modern purse seining developed in America spread, about 65 to 70 years ago, to Scandinavia and Japan, and has progressed from there on. The basic concept may have come to the U.S.A. from the Mediterranean and possibly even from China. To illustrate the variety of shapes and sizes of purse seines in use today some examples of purse seines from various parts of the world are shown in Fig. 1

Mediterranean purse seining is mainly by light attraction as discussed by **Bonnier**, but there is also daylight fishing. Throughout the Mediterranean light fishing equipments and techniques are similar. Most of the sardine and anchovy nets are about 300 m long by 90 m deep made of thin nylon netting and of very small mesh size, mostly 6 mm bar. However, there are certain variations. The net described by **Bonnier** represents an extreme in cheapness and simplicity. These nets are hung-in only five per cent, i.e. five per cent of the stretched length of the netting is slack when hung to the floatline. In other parts of the Mediterranean 20 to 30 per cent is common. Light attraction is usually carried out by anchoring two small boats with either kerosene, liquid gas or electric lights. These are mostly surface lights, but in some areas underwater electric lights are used. In Italy both types are employed, two underwater lights being supplemented by a surface lamp, each being 500 W. The light boats are anchored in a previously fished area, and little use is made of echo sounders, although most boats have one. Fish schools are sometimes located during the afternoon and light boats anchored over them. One or two men are left in each light boat to watch for air bubbles and other signs of fish. If there are no signs after two or three hours, then the light boat is usually moved to another location. A good catch for a night's fishing in Italy and the eastern Mediterranean is two or three tons which is not impressive by most standards, but the catch improves nearer Gibraltar.

In West Africa, especially on the Ivory Coast and Ghana, purse seining for sardinella has developed into a sizeable fishery in the last two decades. Nets are about 250 fm long,

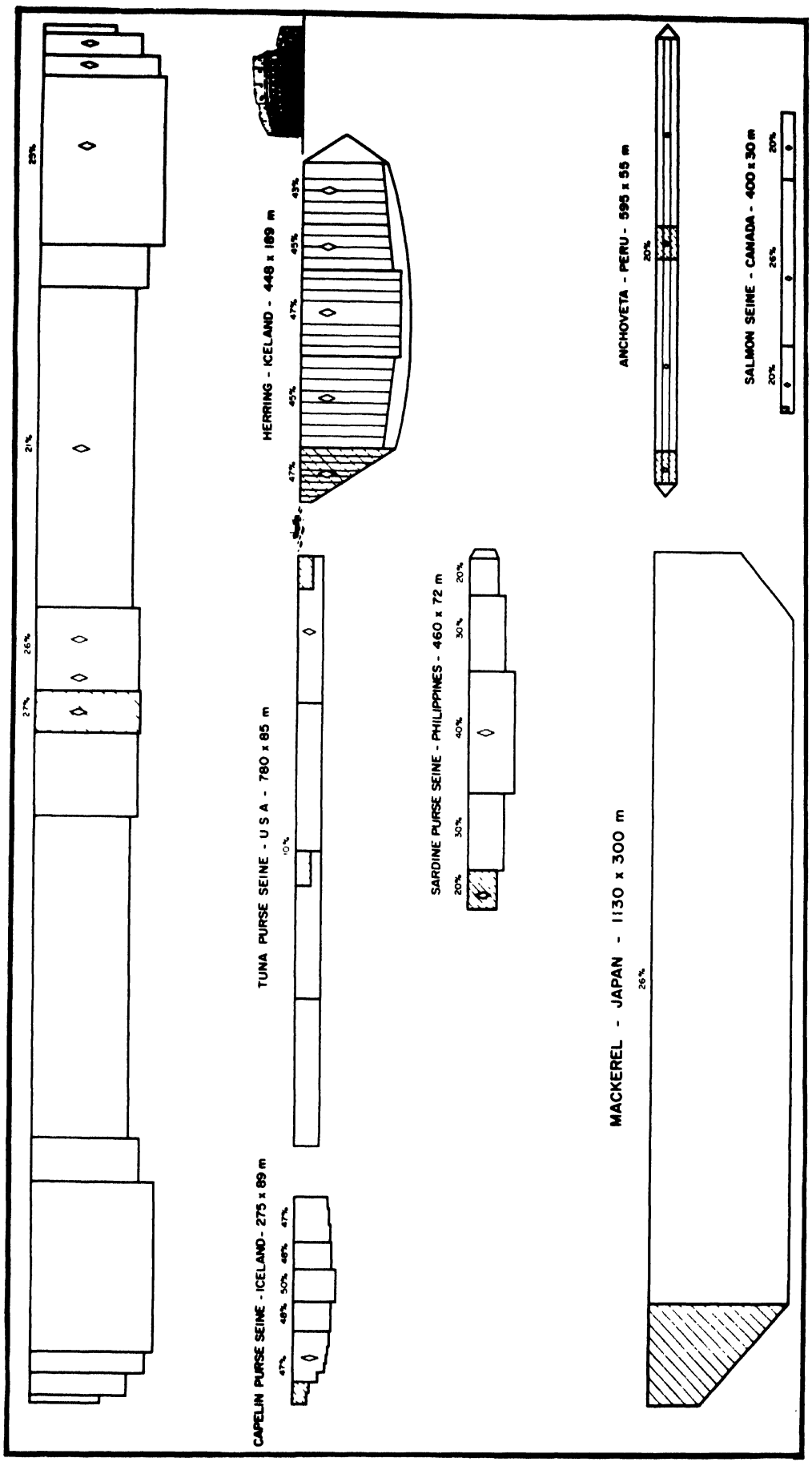

Fig. 1. Top, a 2-boat Japanese tuna purse seine, 1819 × 267 m. Middle, the 425 fm standard American tuna purse seine is drawn to true theoretical sinking depth, which means that the area shown reflects the amount of netting in each seine. Hung-in only 10 per cent, it has a very modest theoretical sinking depth. Latest seines are hung-in about 20 per cent and have, therefore, a somewhat greater fishing depth.

To the right is a relatively small Icelandic herring purse seine. New nets are generally bigger than this, which being 448 × 189 m has an actual pursing depth of about 70 fm. To give an indication of its size, three structures the size of the Colisseum, which is 57 m high and half a kilometre in circumference, would just about fit inside. To the left of the net is a 120 ft fishing vessel typical of Norway and Iceland a few years ago.

The Peru purse seine is somewhat similar to the American tuna purse seine. Depth is less than one-tenth of the length, with two bunts, and is mainly hung-in 20 per cent although some are 30 per cent. Some older types used to be 10 per cent hung-in.

The Salmon seine is an extreme case of a long net which cannot possibly form a bag or a bowl.

The Philippine purse seine is a hybrid net which FAO introduced some seven years ago to the Philippines. Now there is a fleet of about 70 vessels catching 60–70,000 tons per year, using the light attraction method.

The Icelandic and Norwegian capelin seines are considerably smaller than the herring nets, as the capelin is easy to catch when it goes into shallow water to spawn.

The mackerel purse seine which fishes to a depth of 200 m, is about average length and depth for southern Japan, which has the biggest purse seine fishery of that country. Nearly one million tons are taken each year.

The Japanese two-boat tuna purse seine shown here is 1,000 fm long and the biggest are 2,300 m long and 300 m deep. This net still bears resemblance to the traditional unpursed roundhaul nets with deep wings which were used in Japan in the nineteenth century before purse seining was introduced. This seems the only explanation for the contrasting shape of the net in an age when most nets are tapered to the ends, but it may be that when pursed, the depth of the central bunt is insufficient for holding fish since the net is virtually cut in two by pursing, forming two bags for the fish, one in each wing.

and fish detection is mainly visual. The effective fishing season is limited to the upwelling period in the summer. The sardinella prefers cooler water than is found at other times on the surface in these warm countries when it seeks and stays under a thermocline. It seems likely that the use of echo sounding and sonar for locating schools, combined with light attraction for compacting and holding the fish, could extend the fishing season. Using nets of the order of only 20 fm to reach the thermocline, year-round fishing would be feasible. This method is now being tested by FAO Fisheries Projects in these countries. **Dykhuizen** and **Zei** report on the introduction of small lightweight purse seines for local canoes, replacing the traditional surrounding nets (Ali nets). These small seines are big enough to reach down to the fish and are already giving promising results both from canoes and small motorboats of which there are many in Ghana.

In other parts of Africa such as the Congo and off Senegal and Mauritania upwelling is more constant. In these waters we may expect considerable purse seining development in the near future. **Raitt, Losse, Schmidt** and **Hoff** describe what has come to light so far in the Regional Fishery Survey conducted by FAO in West Africa in collaboration with local governments. These authors outline the limitations and opportunities for using modern fish finding techniques in these waters.

Traung (FAO): I am just back from West Africa and I can report that small purse seines similar to the Ghana canoe purse seines have just been used very successfully both in Senegal and Sierra Leone.

Ben-Yami (Israel): In the east Mediterranean tightly hung nets are used for fishing at night with light attraction. The fish reacts pretty stupidly at night when attracted by the light and the sinking speed of the net is not so important, so tightly hung nets which are easy to handle are used. In day time, however, fishing is for small surface schools which swim fast and so rapidly sinking nets have to be used. In this type of fishery more loosely hung nets must be used, although they may be more difficult to handle.

Kristjonsson (FAO) Rapporteur: According to the presented Japanese papers, the beginning of purse seining in Japan was the introduction of a menhaden type purse seine from the U.S.A. with the bunt in the centre. This type of seine replaced traditional unpursed roundhaul nets, and led in due time to considerable purse seining development with increasingly bigger boats of about 40 tons in 1910–1920. After World War II, there was spectacular development in Japan as elsewhere. The main fisheries described in the papers are for horse mackerel and mackerel in the East China Sea, in the area between Japan, Korea and mainland China. The boats need to be big because they have far to go to the grounds, but size is regulated by the Japan Fisheries Agency at about 110 tons. In north Japan two-boat seines are most common, but the change over to one-boat purse seining is beginning. The south is already mainly one-boat. Fairly soon the U.S. menhaden fishery will be the only one using the two-boat method, unless unexpectedly the trend swings back. The system in south Japan is that seven vessels work together, comprising a net boat, light attraction boats and fish scouting boats of 50–60ft equipped with dual frequency echo sounders. Sonar is a newcomer to this fishery. The Japanese did not become sonar-minded until about two years ago. Furthermore there are two carrier boats which hold about 150 to 200 tons each, often in refrigerated sea water tanks because all the catch goes for human consumption. The light attraction boats and net boat stay on the grounds for weeks and even months at a time to find fish schools. They claim that dual frequency echo sounders are better than single frequency to evaluate the density of schools. The nets are all very big, being 1,100 to 1,300 m long, and 150 to 300 m deep. They are of two main types, i.e. so-called shallow nets of 150 to 200 m deep, and deep nets which are about 300 m. The deep nets weigh about 30 tons and cost about $100,000. All net boats have the house a little forward of midships. Pursing is carried out forward but the net is stacked on the aft deck which is about 40 per cent of the length of the boat. The net hauling device, which is a pedestal-mounted power block of huge dimensions, with a V groove width of nearly one meter, can travel across the transom from one corner of the stern to the other. The stacking block rides on a rail under a fairly horizontal boom which extends over the entire length of the deck and helps to flake down this very heavy net. The Japanese believe in using netting material of high specific gravity so it will sink without a heavy leadline. This contrasts with other parts of the world where nylon which barely sinks is used. These deep nets have only about 3 kg lead per fathom which is very little compared to the Icelandic and Norwegian herring seines with 12 to 16 kg per fathom. The skipper of the catcher boat uses the sonar for looking under the lights and to find the edges of the school to see how wide he has to set his net. Often fish attracted to light do not come close but stay at a depth and/or in a very wide circle. This is also the case in the Philippines where the nets introduced by FAO are 250 fm long but are set in a circle of 300–350 fm with a 100 fm towline to herd in the fish.

Nomura (Japan): In Japan the one-boat and two-boat systems are used in three different fisheries—sardine, horse mackerel/mackerel and tuna. In the sardine fishery the two-boat system is most popular and it is operated off central Japan. In the horse mackerel fishery the one-boat type is most popular. In the tuna fishery we use at present both the one- and two-boat system. However, in recent years we have begun converting to the one-boat system in the tuna fishery due to a shortage of labour. The two-boat system is actually better for encircling the tuna because it can be done in half the time. The use of additional boats (these are called attendance boats) for sounding and directing the seine boats is advantageous, but costs are prohibitive especially the cost of manpower and maintenance. In the one-boat system a higher vessel speed is required in order to encircle the fish quickly enough.

Olsen (FAO): I have noticed that some of the purse seines in Japan are of great depth and I should like to ask in this connection if any attempts have been made in Japan to use gear similar to the Norwegian sunken purse seine. This may have been discussed at the 1963 Gear Congress. The seine was weighted with lead of sufficient quantity to cause the floatline to sink, and then supported by additional floats attached to dropper lines which remained at the surface. In this manner deep schools could be caught. Schools of cod at 90 fm depth were caught with a seine of only 55 fm nominal depth.

Nomura (Japan): **Kristjonsson** explained that the Japanese horse mackerel net is 200–300 m in depth. The fishing grounds are 100–300 m in depth. Fishing is conducted at night using light attraction in which a small vessel attracts the fish up from the bottom and they are surrounded by the purse seine. Sometimes the net is actually in contact with the bottom and is gradually pursed and the catch hauled in. The schools are sometimes so large that the net should be very long, up to or over 1,000 m, and the depth should be about 30 per cent of the net's length to embrace schools. Sinking the floatline to obtain a greater effective fishing depth has not been practised in Japan in commercial fishing.

Scharfe (FAO): I would like to call your attention to **Hamuro's** paper which describes Japanese trials to apply sunk purse seines similar to the Norwegian method.

Campion (U.K.): In **Akaoka's** paper on Japanese horse mackerel purse seining it is mentioned that the catch is stowed in refrigerated seawater (RSW). I wonder if someone from Japan could tell us the length of time the fish are kept in the RSW tanks, the method of unloading, whether dry or wet pumping is used, and the percentage of damage to the fish which we understand is for human consumption.

Nomura (Japan): The catches are loaded by scoop nets not by pumps from the net to carrier boat and it takes about one hour to empty the net. The fish are kept in the hold in a mixture of fresh ice and sea water and it takes less than a week for the carrier vessel to return to port.

Gronningsaeter (Norway): If the fish is full of food, how does this affect the keeping quality in refrigerated seawater?

Nomura (Japan): I am sorry that I have no information on this matter but presumably it is not a serious problem since I have never heard fishermen complain about the matter.

Kirkland (U.K.): My company has operated an RSW vessel and the herring are in the tank for a maximum of three days. It has been noticed that if the fish are full of food then when the tank is discharged there is a residue of sludge at the bottom. It seems that this residue is a result of the food being emptied from the stomachs of the fish during their storage period.

Allers (Norway): One particular feature of Japanese purse seining for mackerel is that polyester is being used. Somebody has indicated that the use of polyester could be due to the fact that they want the seine to reach down to 200–300 m. We have in Norway, and I know this is being done in Iceland also, constructed seines of depths up to 200 m, but we still use nylon, and nylon is generally used throughout the world for purse seines. Maybe the Japanese participants could give us a more detailed explanation of why polyester is being used.

Nomura (Japan): In general, horse mackerel and mackerel purse seines are made of polyester and polyvinyl alcohol rather than nylon. Fishermen prefer to use these materials in the East China Sea because of the strong currents. If the net is made from material of low specific gravity the net can become distorted in the current. The specific gravity of polyester and polyvinyl alcohol is 1.38 and 1.31 respectively, whereas that of nylon is 1.14.

Kristjonsson (FAO) Rapporteur: Tuna purse seining started either in Japan or America. **Green, Perrin** and **Petrich** describe the American tuna purse seine fishery. The nets are very big and expensive and used from the biggest purse seiners in the world— up to 700–900 tons. This fishery came into its own, as most other modern purse seine fisheries, after the advent of the power block, invented in the early 50's by Mario Puretic, an American West Coast fisherman of Yugoslav origin, and built by MARCO in Seattle. This started a new chapter in purse seining history throughout the world and opened the door to power handling of nets. When nylon came into use it was feasible to make nets strong enough, long enough, deep enough to envelope the schools far more effectively than was possible in the age of cotton.

In the last 15 years American purse seining has spread from California down to Ecuador. This part of the Eastern Pacific is blessed by peculiarly favourable hydrographic conditions in that there is generally a thermocline in big areas and for long periods of time only 10–20 fm under the surface of the sea. Not only is there a sharp temperature drop but also a drastic drop in the free oxygen content and this is much more important for tuna purse seining. Tuna, and especially skipjack, suffocate quickly if they venture into water with much less than 3 ml/l of free oxygen. Perhaps this is the reason why American tuna purse seines of very modest sinking depth are effective. They only have to reach around a school and sink down to say 20 fm and the fish are trapped, but of course it is not as simple as it sounds. Speed boats are widely used for herding porpoises which travel with the tuna school, running like a Scottish sheep dog around the school.

In the West African tuna fishing grounds thermocline conditions are generally not as favourable as in the Eastern Pacific and consequently deeper nets have to be used. **Sugano** and **Yamamura** describe Japanese tuna fishing in West Africa with giant two-boat seines of up to 2,300 m long and 300 m depth.

In the Celebes Sea and other waters near the Philippines both yellowfin and skipjack schools are plentiful but are so wild that they have defied all attempts at purse seining so far, both in an FAO Project and also by big U.S. tuna purse seiners which have ventured there. Our own net is 700 × 70 fm and this seems insufficient for conventional tuna purse seining of surface schools. Shown in fig 2 are echograms of submerged tuna schools which I recorded in the Celebes Sea in 1968.

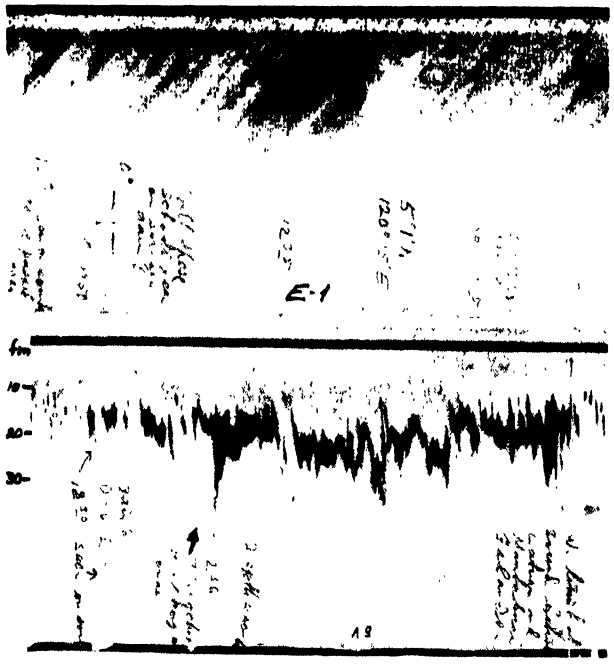

Fig 2. The upper part is a sonargram taken at full vessel speed and with the transducer aimed straight forward. The big school in the centre is estimated at several hundred tons. This was at noon on a sunny day and all yellowfin and skipjack schools were submerged and stayed at 15–30 fm depth, as shown in the lower echogram taken with a sounder. Tuna and skipjack schools are possibly less panicky when submerged and trials may be made with Scandinavian style sonar-guided purse seining. The use of sonar would also make possible tuna searching around the clock to supplement the visual spotting from the crow's nest which has a longer range but is limited to times of day when the tuna schools are on or near the surface

Petrich (U.S.A.): The introduction of power blocks certainly changed tuna fishery a lot, but the most important contribution to the development was the introduction of nylon nets.

Hamre (Norway): Purse seining for bluefin tuna off the coast of Norway has not been mentioned. Although the total catch is not great the net used has some interesting features. It is about 500 fm long, 65 fm deep, hung-in 60 per cent. Only the bunt end is of strong netting and the rest is of light netting,

capitalizing on the fact that tuna and other scomberoids avoid net walls if there is sufficient space for them to swim around within the net. We have suggested that this net and method could also be used in the tropics, but there has been no response. Some time ago a set was made on a school of yellow fin and skipjack. We succeeded in keeping the school in the net until the strong portion was taken in. The mesh size is 15 cm and most of the skipjack was filtered out.

Ben-Yami (Israel): **Hamre's** bathykymograph study of the Norwegian purse seines stimulated very much that study which resulted in the design of the hybrid tuna purse seine in California.

Green (U.S.A.): In the California tuna fishery we are using a mesh size of 4¼–4½ inches. In certain areas one can increase the mesh size to get a deeper net and save material. We have made a seine for experimental fishing for Hawaian skipjack. The mesh size there is 8 inches in the bottom.

Petrich (U.S.A.): I would like to point out that there is a considerable difference between Norwegian purse seining for bluefin tuna and the American fishery for yellowfin tuna, which are taken mixed with many other types of fish, such as porpoises and sharks. Sometimes catches of tuna will amount to 100 tons or more in one bag of the net which is a considerable weight, and occasionally a set may be up to 350 tons. This requires that the netting be extremely strong. Furthermore, extremely severe weather makes it necessary to use the strongest material available which is nylon. However, we are still learning.

Jakobsson (Iceland): In **Kristjonsson's** echograms I noticed that the range was extremely short. Could you please tell us more about this.

Kristjonsson (FAO) Rapporteur: It is true that the sonar traces were recorded at a range of only 500–600 m, although the sonar had a maximum range of 2,500 m. A possible reason for this is that before I went on board the FAO Project vessel *Maya-Maya* the sonar was not properly tuned nor had it been used much before and many parts were not functioning properly. There was no thermocline and the oceanographic conditions seemed to be favourable for sonar use.

Petrich (U.S.A.): Raschel netting is now used in about 30 per cent of American tuna purse seines but knotted braided twine is preferred in the heavy netting sections such as the bunt. Some boats are using Raschel type netting hung vertically for greater strength, and with good results.

Kristjonsson (FAO) Rapporteur: South American purse seining is described by **Hellevang,** by **Villaneuva** and by **Gudmundsson** and **Gamberale.** The Peruvian anchovy fishery, as we all know, is tonnage-wise the biggest in the world today having reached 10 million tons per year. It amounted to practically nothing 15 years ago. This is the most spectacular development that has ever happened in fisheries in the history of mankind. Unfortunately all this anchovy goes for fishmeal and oil and therefore the landed value of the fish is very low, perhaps of the order of 10–12 dollars per ton. The nets used are very similar to the U.S. tuna purse seine in principle, with two or three bunts because catches are very big. It is difficult to handle very big bags or bunts so the technique used is to keep alive half the fish in one part of the net while coping with the other half. Fishing is in shallow water, usually inside 30 fm depth, within 70 miles from the coast. The fishing area is 1,200 miles along the coast. Spotting is by bird activity and by seeking brown patches and fish on the surface. Airplane spotting does not work well in Peru because the sea is often very opaque. **Hellevang** spoke about a few skippers who, having learned to use a sonar and making good use of it, come to depend on it entirely and do not want to go to sea without it, but such skippers are a minority so far. Boats have been getting bigger but they have probably reached the maximum or optimum size, carrying 300 to 350 tons, according to **Hellevang.** These are difficult to fill in a single day's fishing, and due to a local regulation the boats must bring in each day's catch to avoid spoilage. There are 1,400 purse seiners in Peru so here is one fleet with statistically valid fleet numbers for systems analysis studies.

In Argentina there is a traditional lampara fishery for anchovy but no purse seining now except on an experimental basis. FAO has one 110 ft vessel exploring the Northern Patagonian Shelf from the Rio de la Plata to well south of the main fishing port Mar del Plata. It is too early to pass judgement, but I gather from **Gudmundsson,** our sonar purse seining skipper on the exploratory vessel, that he thinks a million ton anchovy fishery could develop there. We will not see a Peruvian-sized venture, but certainly something very substantial.

Gudmundsson (FAO): I feel that it will take quite a few years before the million ton mark is reached in the Argentinian anchovy fishery. Two or three purse seiners will come into operation this year. Weather conditions are often adverse and it will be harder to catch the anchovy there than it is in Peru. For eight months of the year the anchovy is 100–150 miles off the coast.

Hjul (U.K.): Will different types of boat and operation be necessary in Argentina to those used in Peru? Does **Gudmundsson** expect that the European type of purse seiner will be adopted?

Gudmundsson (FAO): Yes, I think the operation will be different and that the fishery further off shore will be a sonar-guided purse seine fishery with Scandinavian type vessels.

Allen (U.S.A.) Chairman: Several years ago, MARCO had a 66 ft west coast of South America style purse seine boat operating for a year in the Mar del Plata area and we did find that the conditions there, during certain parts of the season when the fish were close to the coast, were suitable for purse seining, but at this time of year schools were only of 5 ton dimensions more or less. We did not find any large schools of fish during that survey and were not able to travel off shore with that size vessel. Our conclusion was that it would require a great deal of investment to bring in the fish.

Gudmundsson (FAO): The coastal season lasts from mid-September until late October. Only small open boats are involved and they use a lampara net, not a purse seine. In the coastal fishery, schools are occasionally seen on the surface, but most are submerged.

Olsen (FAO): Why do they still use a skiff in South America and elsewhere, for instance in the American tuna fisheries, when this is no longer found to be necessary in the Northeast Atlantic?

Hellevang (FAO): To fill a 350 ton vessel in one day can only be achieved normally on some 40 days in a year. This year, however, there was an improvement on this figure. Anchovy are quick in clear water and a net must be set in exactly the right position. It is not possible to make use of wind and current to keep the boat clear of the net and therefore use has to be made of the skiff. The only way to get rid of the skiff would be to adopt bow and stern thrusters on purse seine vessels.

Sams (Chile): I am very much in favour of using a skiff from the point of view of safety and manoeuvrability. A net, with 150–200 tons of anchovy, is very hard to handle without a skiff and particularly hard if you use a two-bunt net and split the catch. With a skiff currents and wind can also be disregarded.

I would like to comment on airplane spotting in turbid water. You can detect fish in such water if you know how to do it. In southern Chile (Talchuano) we are using the airplane just as successfully as in the north, although there are places near the outflow of rivers where the water is very turbid at times. Search by airplane was carried out in Mar del Plata, Argentina, for 20 days alongside the research vessel operating there at that time. No great masses of anchovy (anchoita as it is called there) were ever found although a big area was covered. Most of the anchoita was small, 6 to 8 cm, but very visible. Quantity was not considerable for fishmeal, only for fresh fish marketing.

Petrich (U.S.A.): The purse seine skiff is being eliminated in some instances by securing the bunt floatline to an outrigger that has a rubber tyre for a spring (shock cord), but the skiff is necessary to hold the vessel clear of the net, turn the boat and improve the brailing operation.

Goodlad (Canada): In eastern Canada we have a coastal fishery where it is considered necessary to use a skiff. We are fishing up to 20 miles offshore and the water depth is between 2 and 10 fm. Power thrusters on fishing vessels have not been found to be convenient so far for handling boat and net together.

Gudmundsson (FAO): The question as to whether to use a skiff or not depends also on the construction of the net. It is much easier to keep the vessel out of the net if the length depth ratio is 3:1 rather than 10:1. In Argentina I have been successfully working without a skiff with a net having the ratio of 4:1 using one stern thruster.

Allers (Norway): On the question of the necessity for using a skiff, we can turn to east Canada where they occasionally make tow-sets. When fish is scarce it has proven practical to keep the net open and tow it with the skiff resulting in a catch of 50 to 80 tons, whereas the registration on sonar or echo-sounder would indicate only 5 to 10 tons.

Kristjonsson (FAO) Rapporteur: The American Pacific coast vessels purse amidships with the net astern, so they haul the stern of the vessel into the net all the time. As long as they do this they will need a skiff or lateral thrusters. More likely the skiff—because of the very low depth/length ratio (1:10) of the nets. This is quite different from the Scandinavian system of pursing up forward, hauling in the net with a pedestal-mounted power block (often mounted at the front end of the boat deck) and using relatively deep nets of 1:3 depth/length ratio, all of which makes it easier to manage without a skiff. Some Icelandic skippers take a pride in managing altogether without even an outboard powered dingy or rubber raft, even without lateral thrusters.

Let us now deal with the North Atlantic or rather Scandinavian purse seining techniques. **Jakob Jakobsson's** paper on the Icelandic herring search and information services, which we have already dealt with, forms a background to the paper by **Gislason** on the Icelandic technique of sonar-guided purse seining. So does another paper by **Jakobsson** which he presented at the 1963 Gear Congress and which is still valid and appears in the book *Modern Fishing Gear of the World: 2*. The present paper by **Gislason** refers several times to the latter **Jakobsson** paper and complements it, tracing the change over from two-boat to one-boat seining, introduction of the power block, the nylon net and the evolution of sonar-guided purse seining in Iceland which saved the Icelandic economy at a time when the herring changed its behaviour and could no longer be caught by the old method. It could not be seen on the surface; it could not be caught without sonar or without deep nets. Deep nets could not be handled without the power block. **Gislason** discusses the skipper's duties, such as checking that all equipment is in order, planning the trip, the all important listening to news including listening to a multi-channel radio (7–9 channels simultaneously) to find out how the others are doing and where they are; making fullest use of the thermograph on the bridge to see when the crossing is made into another type of sea, and of course patient and always watchful use of the sonar and especially the aural signals. He repeats in this paper the safety rules from the Code of Safety prepared jointly by FAO, ILO and IMCO and recently published by ILO. This is Part A dealing with operational safety and is aimed at skippers and crews. Part B—ship's features—is in preparation and is addressed to the ship designer and the shipbuilder. **Gislason** has wise words to say about bad weather tactics. With Scandinavian type vessels that have the wheelhouse aft and the pull on the net well forward, it is now possible to set in force 6 and finish a set in force 8 but this is of course hazardous without thrusters. **Gislason,** apart from being a top skipper in Iceland during the summer, is a teacher at the Nautical School in Reykjavik. Shore training in the use of fish finding equipment and fishing tactics has recently been initiated in the school and **Gislason** feels that a training vessel is also needed. **Thorsteinsson** gives details of Icelandic purse seines for herring, capelin and cod. Cod seines have not been built much in Iceland in recent years, for although these nets gave good results in 1963 and 1964, since then the cod schools have not been sufficiently dense. On the other hand a fishery for cod and haddock with small boats of 2 to 5 tons using baby purse seines is gaining ground on the north coast. When big boats were fishing for cod the nets had only 3 floats per fathom which was not enough to keep them above water. They just sank to the bottom but were lined up to balloon floats on the surface. I should add that herring purse seines sink too.

Hamre and **Nakken** trace the early history of the introduction of purse seining in Norway and its subsequent development. The two-boat method with a crew of some 24 people was commonly used in Norway until 1963/64 when all boats converted to one-boat purse seining in the same style as has been described for Iceland. This paper pays a very generous tribute to Icelandic pioneering of this method. There is one important difference in tactics between the Norwegian and the Icelandic methods. The Norwegians carry a bas boat with a small sonar which makes it much easier to study the school and guide the setting. When in keen competition or when the circumstances demand it however, the skippers also use the Icelandic technique of aiming the set with the ship's sonar alone which is more tricky. After one-boat purse seining and sonar fishing became well established in Norway the capelin fishery started increasing steadily, having reached an all-time high this year (1970) of 900,000 tons. Similarly, a big new purse seine fishery opened in Norway for mackerel. The Norwegians used to catch 10 to 15,000 tons of mackerel per year, mostly in driftnets, but the use of sonar purse seining resulted in catches of over 800,000 tons a few years ago. It seems to have been too much for the stock and now the mackerel as well as the Atlanto-Scandic herring need conservation measures to build up strength again. Possibly the next chapter to be written in Icelandic and Norwegian purse seining is fishing for blue whiting in the Norwegian Sea and eventually other neglected species.

Kudryavtsev and **Torban** describe U.S.S.R. purse seining, which conforms with what is standard practice in Norway

and Iceland. The Russians did not pay much attention to purse seining in the Atlantic until relatively late, but their purse seining on the Pacific coast of Siberia is old, as is that in the Black Sea for horse mackerel, bonito and anchovy but on a small scale.

Combination fishing vessels in Canada are dealt with by **Kristinsson.** He says that some new boats on the east cost of Canada are fitted not only for combination fishing but for quick conversion at sea, meaning that they can carry a purse seine when trawling and when they are trawling on the bottom they can switch over to a midwater trawl. They are ambivalent boats of about 100 ft and smaller. Combination fishing is in fact practised in many parts of the world and I am always surprised when I meet the argument that combination boats are inefficient for all fishing and that there has to be a sacrifice. All Icelandic purse seiners are combination vessels, which perhaps is fortunate as many of them are now trawling and not purse seining at all. All of them are fitted for longlining and gillnetting, and several go through an annual cycle of purse seining, trawling, longlining and gillnetting. In the Mediterranean most purse seiners trawl in the winter. In the Philippines some of the purse seiners fitted out with the help of the FAO Project now convert daily between night purse seining and day trawling. In Malaysia many trawl boats of 30–40 tons carry a purse seine. In the U.S.S.R. experiments are in hand with purse seining over the stern of big stern-trawlers, and consideration is being given to purse seining over the bow, as do the Malaysian boats already mentioned.

Birger Olsen (Norway). Written contribution.

Before the outbreak of World War II a method was developed in north Norway to prevent tearing the net when purse seining for coalfish in shallow waters. This method has since been successfully applied to purse seining for herring and capelin.

The method employs inflatable plastic floats of 70 to 80 in circ. attached to the purse rings by lines, the length of which is adjusted to prevent the leadline from sinking beyond 2 to 4 fm above the bottom. The effective length of the lines is easily and quickly adjusted before shooting the net and the floats can also be quickly disengaged from the purse rings when not required. The method is therefore very useful for fishing in localities with variable depth and hard bottom conditions.

Fishing for capelin in 15 fm of water with a 200 × 45 fm seine the length of the lines should be 10 fm. Such a seine might have 30 rings and about 20 plastic floats which are attached to each ring in the middle of the seine, but only one on every second ring at both ends. This prevents the most vulnerable mid-section of the seine from touching bottom. However, if the seine is relatively heavily "leaded" one float for each ring throughout is recommended.

Instead of the pear-shaped floats, cylindrical plastic floats are sometimes used. Their shape facilitates easy winding of the line on the float, which is how the line is stored ready for shooting the net. In the case of the inflatable pear-shaped float a spliced rope loop of a diameter a few inches less than that of the fully inflated float is put around it when half-inflated. When fully inflated a groove is formed in which the line is wound.

The full length of the line may be up to 20 fm and adjustment of the effective length is made by doubling the end of the line which is attached to the purse ring. The method has several advantages: when fishing in shallow waters and the fish are thinly spread and swimming in one general direction, a rather "open" seine can be shot and pursing can proceed relatively slowly. This will usually yield a larger catch than when pursing quickly to prevent the groundrope from touching bottom too heavily. Similarly, in areas of strong currents the necessity to keep the seine off the bottom is obvious, and the method therefore facilitates purse seining in many localities, which could otherwise not be efficiently exploited.

For capelin fishing in Norway this method is also used by the very largest purse seiners, with seines of 240 × 55 fm and 1,200 kg leadline. Catches when applying the method have been up to 300 t/set. The method is also still much used for coalfish seining with seines up to 320 × 60 fm with 1,500 kg lead.

Hamre (Norway): In connection with **Olsen's** description of a method of reducing operational depth of a purse seine when fishing in shallow water, he observed from net depth recorder traces that by using a long towline and by pulling this in with high power immediately after the circle is completed, one reduces the sinking speed considerably and might even be able to lift the leadline in the centre of the net before pursing is started. He felt that this could also be a method of reducing the risk of damaging the net when fishing in shallow water.

Petrich (U.S.A.): In the United States we have a method for regulating the depth of the net as it fishes. We use what we call suspenders that are spaced 10 to 15 fm leading from the floatline to the leadline to give a fishing depth of 10, 12, 18, 25 fm depending on what depth we are fishing.

Goodlad (Canada): In eastern Canada we have a fairly new purse seine and pelagic trawl fishery for Atlantic herring. The number of vessels is fairly small—less than 100 in total and not more than 50 of these being continuously effective units. The catch is high at over half a million tons this year and individual catches exceed 20,000 tons per annum. The fishery takes place in summer in the Gulf of St. Lawrence, in autumn around the Magdalen Island and by November it is concentrated on the South Coast of Newfoundland. In spring the hub of activity moves back towards the Magdalens and the Gulf. There is also considerable summer fishing in the Bay of Fundy.

One of the most distinctive features of the fishery is that it generally takes place in shallow water, especially on the South Coast of Newfoundland and the Bay of Fundy where sets are often made in less than 3 fathoms and this obviously has a large bearing on technique and operation. The other remarkable feature is the volatility of the industry as it is technologically very young.

In the purse seining sector three main influences have been apparent. That from the west coast of Canada, from Nova Scotia and from Scandinavia. The most successful of these is probably that from British Columbia. When the fishery failed in British Columbian vessels and crews moved into an almost identical fishing environment in Eastern Canada—shallow water and bad bottom with large schools of herring in relatively sheltered waters. The west coast seiners, with their high-slung power blocks and forward superstructures have proved very efficient.

The Scandinavian style of fishing meets with less success. Some Norwegian built vessels have been fishing for several years and have now found the optimum technique for them to be between that of the Scandinavian and the British Columbian. The main problem has been in manoeuvrability and net tearing. It has been found much easier to repair the horizontally stripped Canadian nets than the vertically stripped Scandinavian. The Canadian nets are also usually heavier, the lightest twine being 210/12 (R 300 tex).

There is considerable controversy over the "Taper Bunt" but no quantitative evidence has yet been put forward as to the advantages of the taper of the square bunt. The west coast vessels use the square bunt and take a little longer to dry up the catch. This is compensated for by increased catches. However, some of the most successful fishermen use a taper or semi-tapered bunt.

The fleet make-up also demonstrates the evolutionary stage of the fishery at the moment. No one vessel design has been settled on. There are boats with houses aft, houses forward and houses in the middle. Sizes vary from 50 ft shore seiners to 160 ft barges. There are boats that convert to sealing, some that convert to trawling and more that carry cargo. Most new vessels tend to be on the B.C. style and an increasing number are being built with a multiple capacity with special consideration for midwater trawling, Although some vessels to date have been built as multi-purpose, few have been used as such and most have either seined or trawled for herring.

The disadvantages that the Scandinavian style vessels have found are mainly in manoeuvrability and handling gear with a small crew. The average Canadian crew size is about 7 men compared to about 10 in the eastern-Atlantic. Problems of skiff usage have also been apparent especially when the net freezes in the bin and a fast set is required. The European boats which rely on the drag of the net in the water to haul it over the side miss sets that Canadian style seiners can make by towing the net out with the skiff. In shallow water however, the skiff or bas boat used in the Norwegian manner with a sounder sonar on board has often proven a boon either for doubling the searched area in a Bay or for scouting shallow portions and for guiding the setting. Some of the newer B.C. vessels are beginning to use the skiff in the same way. The Scandinavian style of vessel seems to be more useful for open water work and for carrying a load in bad weather, and the degree of crew comfort is greater on the European boats.

Some of the setting areas are so tight that larger boats use the skiff on the bow to help turn them offshore as they set. Neither is it uncommon for boats to touch bottom as they set the seine. There are many cases where boats have grounded as they pump herring into the hold and have to await the incoming tide to take them off. Obviously in such circumstances special techniques evolve.

One of the most important factors is to find herring on the best bottom possible. Another is to try to drag the seine on the bottom as little as possible. This involves pursing the boat into the net, rather than the net to the boat. The high slung power block then lifts the net off the bottom, and as it lifts the vessel is towed backwards around the circumference of the set net by the skiff. Obviously this kind of fishing can only take place in smooth water with little wind.

In spite of heavy nets often only having 20 fathoms hung depth, a great deal of tearing takes place. It is also noticeable that often the greatest quantity of net tearing is done by those who catch most herring which would appear to relate "boldness" with fishing success. It is not uncommon to have five sets and five "tear-ups". Net construction is in straight horizontal strips, and speed of mending is of greater importance than meticulous care—hence an end to end tear might mean one day ashore in Canada whilst on a large Scandinavian net of vertical strips it might mean 3 or 4 days' work.

Instrument usage in Canadian shallow water is much less than the deep water fisheries of Iceland or Norway. The reverberation problem of using sonar in depths of less than 10 fathoms are obvious. In such situations most reliance is put on the echo-sounder and visual spotting. On the sands of the Magdalen spawning grounds spotting is almost entirely visual. In summer and early winter when the fish are offshore sonar is used but relatively small range units tend to predominate. There tends also to be a predominance of the C.R.T. presentation sonar types for facility of setting without using the skiff as a bas boat.

On deck, gear is also varied. The most common block is the boom-slung Marco. There are also a few Norwegian net winches. Many of the smaller boats do not use purse winches and wire purse lines, but haul a nylon purse line on capstan heads with an ancillary hydraulic spool. A few of the Nova Scotian boats incorporate a hydraulic roller on the starboard rail to aid drying up the square bunt. One trend is towards multi-purpose or dual purpose vessels such as seiner/midwater trawlers.

Thorsteinsson (Iceland): Icelandic skippers have used a similar method as that described by **Hamre** for catching capelin in shallow waters, **Hamre** and **Nakken** state that for the Norwegian herring purse seine fishery the hanging-in ratio to the floatline is about 35 per cent in the bunt and some 50 per cent in the centre of the net. This is roughly the same as in Iceland. But the hanging-in ratio of the leadline is reported to be some 10 per cent less than that of the floatline, making it very much longer than necessary. I am wondering why this difference is so great. In Iceland this difference in hanging-in ratio is approximately 2–6 per cent. Even this difference is rather great, resulting in the fact that the leadline is pulled out by the netting over the bulwark during the shooting so that the net may tear. Has this been a problem in the Norwegian fishery? In Iceland we have tried one purse seine with a hanging-in ratio of only 1 per cent difference between the floatline and leadline and there were no hauling difficulties.

Hamre (Norway): When using a power block the leadline comes in quicker than the floatline because the strain is mostly on the floatline. It was also believed by some fishermen that a long leadline increases the sinking speed of the net though this can be disputed.

Ben-Yami (Israel): Lower hang-in on the leadline helps to keep it down at the beginning of the pursing operation.

Petrich (U.S.A.): I believe that leadlines should be longer or made of rubber so that the net can be free to sink to its maximum depth. The deeper the net is made, the more the leadline should increase in length in ratio to the floatline. As the net gets deeper the leadline must be longer to allow for the extra length needed to complete a balanced shaping and maximum sinking depth.

Goodlad (Canada): In Canada the leadline is, in some cases, made shorter than the floatline. This is done for what is called "skimmer fishing", i.e. fishing on scattered layers of herring, using the main vessel and the skiff to actually tow the two ends of the net through the fish. Then the shorter leadline comes in advance of the floatline and brings the net underneath the fish, which then collect in the bag so created.

Sigurdsson (Iceland): In **Gislason's** paper, I feel the need for more information about the training facilities available at the Nautical School in Reykjavik. The fact is that a complete modern sonar set is used in the training of skippers. We are also planning to expand the training programme to incorporate repairing radar, sonar, etc. We feel these training aspects are very important as large savings can be achieved by giving the skippers technical knowledge of their equipment. It sometimes happens that big vessels have to go to harbour for minor repairs which could easily have been fixed on board. The School has recently published a guide on minor repairs of sonar and other navigational instruments. I would like to have information from other institutions in other countries about the availability of training vessels which I consider a necessary complement in advanced training programmes.

Kingsley (Canada): I would like to point out that the College of Fisheries in St. John's, Newfoundland, does indeed have a training vessel. It was originally a longliner, 120 ft in length, equipped with radar, Decca Navigator, Loran and echo sounding equipment.

Oswald (FAO): The FAO Fishing Training Centre in Korea employs seven training vessels ranging in size from 50–120 gross tons. These vessels are equipped for Danish seining, purse seining, trawling, tuna longlining, gillnetting and bottom longlining. In Korea it is very important to train fishermen and marine engineers and we place considerable emphasis on training at sea with project vessels operating on a semi-commercial basis. In this way the trainees not only learn by participating in the fishing operation but the Centre can supplement its budget with fish sales.

Other FAO Fishermen's training centres in Singapore and Malaysia have—or will have—two training vessels each.

Smetten (U.K.): Two training vessels, which do not appear to have been mentioned, have recently been built to designs prepared by the firm I represent. The first one is a fisheries training vessel for the Government of Quebec, Department of Education, and has many unique features. It is designed for sterntrawling, sidetrawling, purse seining and longlining. Dormitory accommodation is provided for students and the mess room can be converted into a lecture room with cine screen, etc. The bridge is laid out like a classroom with instruments and controls sector-grouped so that fish finding, navigation, ship control and fishing gear control are all positioned for optimised efficiency with ample space for instruction. All fish finding equipment is duplicated and of different manufacture to provide experience of different instrument types. The second vessel has been built for the Government of Kenya and, although smaller and less sophisticated than the Canadian vessel, incorporates blast freezers and refrigerated hold and is designed for a combination of fishing methods including sterntrawling, longlining and dipnet fishing.

Purse Seine Design and Construction in Relation to Fish Behaviour and Fishing Conditions

Y. Iitaka

Conception et fabrication de la seine coulissante en fonction du comportement du poisson et des conditions de pêche

Une vitesse de plongée élevée et une faible résistance au courant, qui sont considérées comme très importantes pour les seines coulissantes, sont favorisées par le choix d'un matériau lourd pour le filet, d'un fil câblé dur en filaments continus et d'un filet sans noeuds. L'emploi du filet noué qui a une meilleure résistance à la rupture doit être limité aux parties soumises à une contrainte particulière, telles que la poche et les bordures renforcées. La chute étirée des seines coulissantes est comprise entre 12 et 15 pour cent de la longueur pour une pêche de surface et entre 30 et 50 pour cent pour une pêche profonde. Dans les seines coulissantes japonaises la quantité de lest par mètre de ralingue de plomb se tient entre 1,0 et 2,5 kg.

Diseño y construcción de redes de cerco teniendo en cuenta e comportamiento de los peces y las condiciones en que se desarrolla la actividad pesquera

La velocidad de inmersión y la escasa resistencia a la corriente, cualidades importantes en las redes de cerco de jareta, resultan favorecidas con el empleo de material pesado en los páños de la red, hilo de filamento continuo muy colchado y malla sin nudos. La malla con nudos, que resiste mejor a la ruptura, debe limitarse a aquellas secciones sometidas a esfuerzos especiales, como el copo de la red y las cadenetas. En la pesca de superficie, la altura de la red de cerco, extendida, oscila entre un 12 y un 15 por ciento de la longitud de la misma, y en la pesca en profundidad, entre el 30 y el 50 por ciento. En las redes de cerco japonesas, la cantidad de lastre por metro de relinga inferior oscila entre 1 y 2,5 kg.

THE purse seine in Japan is used principally for catching herring, sardine, mackerel, horsemackerel, anchovy, pilchard and tuna. Since these fish are fast swimming, the net must surround them and be pursed as quickly as possible. The success of the operation depends largely on the speed of setting and pursing, which are in turn largely dependent on the sinking velocity of the net.

Netting material

The choice of netting material for purse seine is very important. The faster it sinks, the better it will perform. Heavier and harder continuous filament twine should be more efficient, if we discount the handling properties of materials. Hard laid twine of continuous filament has less hydrodynamic resistance than a soft laid twine made from staple fibre (Iitaka, 1957). Experiments showed that the resistance of netting made of continuous filament twine was about 20 per cent less than that made of staple filament twine. The relative sinking speeds of netting of different materials used in Japan is shown in fig 1. Results show that the difference in sinking speeds cannot be ignored.

The catching capacities of cotton and Kyokurin purse seines have been compared (Iitaka, 1957). Kyokurin is a mixture of polyvinylidene chloride and polyamide. Both seines were alike in design except for netting material and were operated on the same fishing ground during the same fishing period. Also, the captains' fishing abilities were considered to be approximately equal. The average mean logarithmic catch for the cotton seine was 1.65 and for the Kyokurin 1.99. This difference is considered to be due to the relative sinking speeds of the two nets. It was found, by a model experiment (Iitaka, 1958), that a Kyokurin seine sank faster than a cotton seine.

There are many other factors to be considered when selecting the twine material for a purse seine. The tensile strength, its tendency to deteriorate, type of knot and economic considerations must all be taken into account. As no single material in use today possesses all of the desired properties in full, the material should be selected according to circumstances.

Type of netting knot

Since most seines are extremely large, the resistance of a whole net working in water is very large. Consequently, the performance of a purse seine may also vary with the type of knots used to make the netting.

Many experiments have indicated that knotless netting has less resistance than knotted netting. Generally, the resistance per unit area of netting varies with the twine size, mesh size and current speed as represented by:

$$R = f\left[\left(\frac{D}{L}\right) + g\left(\frac{D}{L}\right)^2\right] V^2,$$

where D is the twine diameter, L the bar length of a mesh, V the water speed and f and g are constants. The constant f would vary with the different twine materials used and g would vary with both the twine materials and the different types of knot used.

According to tests with cotton netting set perpendicularly to a uniform current, the values of g were found to be: knotless 0.218, reef knotted 0.255 and sheet bend knotted 0.272 (Miyamoto, 1952).

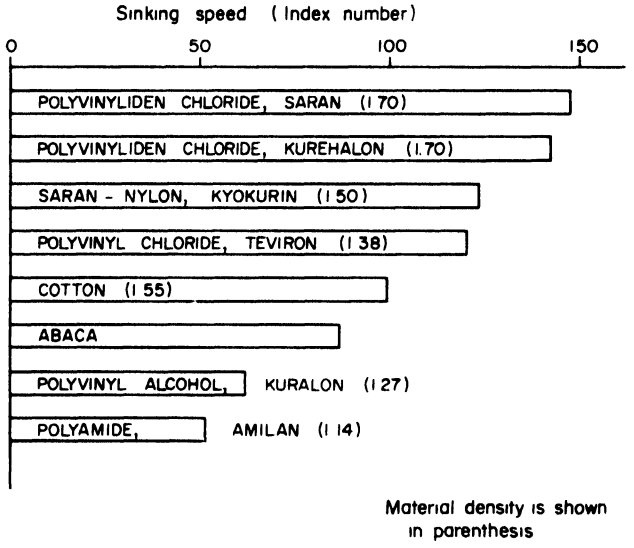

Fig 1. Comparison of the sinking speed of twines of different materials. Basis is cotton as 100. (Shimozaki 1959)

Another important factor in evaluation, however, is the relative strength of the three types. According to Kondo (1959) the knotted netting was superior in this regard. Consequently, it can be assumed that the section of a seine which is put under the least strain should be constructed of knotless netting to reduce resistance; this is the larger part of the net which includes the wing (or wings) and body. The bunt and selvage sections, which absorb the major strains of hauling and weight of concentrated fish, should be constructed of knotted netting. In situations of strong tidal currents where tearing of the wings may be a problem, the wings and body should have narrow strips of knotted netting of heavier twine installed vertically at frequent intervals. This serves to limit the extent of any tearing.

Net size and depth

The size and depth of a purse seine must be determined by the dimensions of the boat used, the species and behaviour of fish caught and the fishing method and conditions. Nagamune (1932) suggested that it is easiest to operate when the stretched depth of a purse seine lies within the range of 8 to 17 per cent of the net length. In practice, according to Donald (1930), the stretched net depth of ring nets in California was about 15 per cent of net length, but only 10 to 13 per cent for purse seines. However, in order to catch deep swimming fish or fish which sound when encircled, e.g. horsemackerel, the net must be relatively deep. This results in seine designs with a net depth which is 30 to 50 per cent of the net length.

Figure 2 shows the relationship between the net length and the stretched depth of purse seines used in Japan.

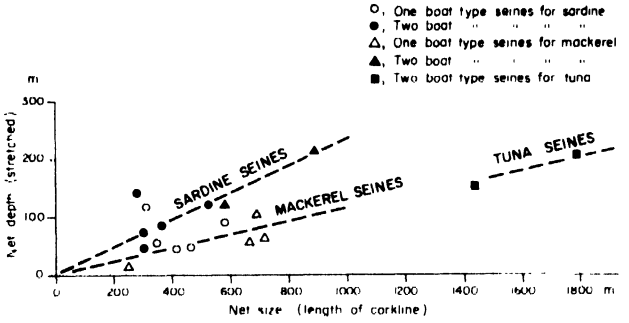

Fig 2. Relationship between the net depth (stretched) and the net length for Japanese purse seines. (Miyazaki 1964)

From this it can be seen that the ratio of the net depth to the net length ranges from 10 to 50 per cent; the ratio for two-boat seines is larger than for one-boat seines; and the size of net used has a tendency to become larger with increasing size of fish. The latter is thought to be due to fish behaviour.

In inshore purse seining, small sized fish such as anchovy, pilchard and sardine are mainly caught. The depth of these fish schools changes with time of day and weather (Inoue and Ogura, 1958). Therefore, a purse seine designed for them is rather deep. On the contrary, in deep-sea purse seining large species such as skipjack and tuna are sought. These fish are fast swimming but normally are

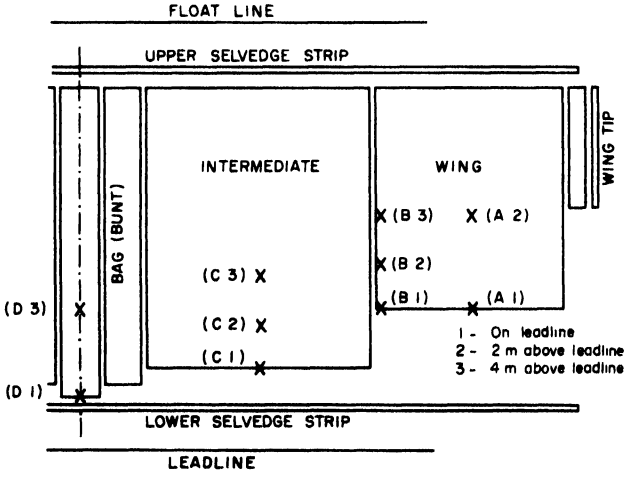

Fig 3. Positions on the 1:10 model net where depth-meters were attached

near the surface. This results in a long and relatively shallow seine.

It is recognized that fishing with a deep seine is technically more difficult than with a shallow one. This is why the taper of the wing of this type of seine is steep, since excess netting is liable to be entangled with the rings and purseline, making it difficult to purse. Model experiments and field observations for this type of seine have confirmed this (Iitaka, 1965). Figure 3 depicts the locations on the seine at which the depth measurements were made. Results of the measurements are given in fig 4. It is

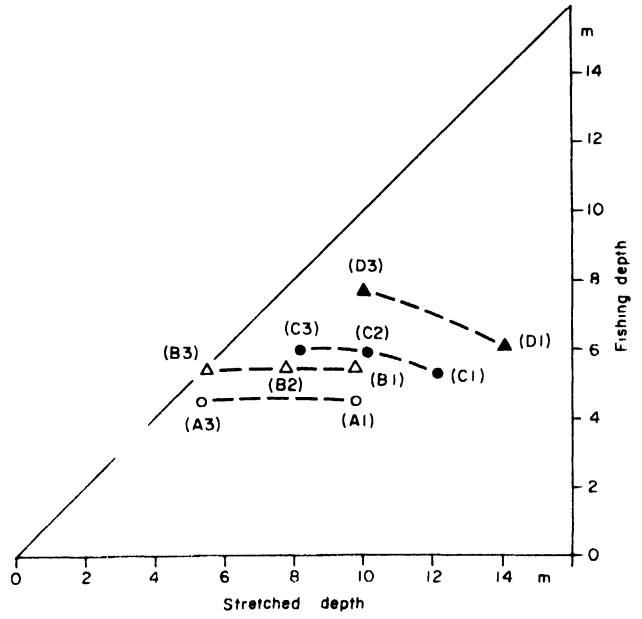

Fig 4. Showing the difference between the stretched depth and the actual depth of the bottom of a 1:10 model of a deep type purse seine used in coastal Japan

evident that point A3, B3, C3, and D3 reach depths almost equal to the stretched depth, while A1, B1, C1 and D1 do not reach even to half the stretched distance. This shows that there is much loose netting around the purseline during pursing.

Figure 5 indicates the relationship between the tension in the purseline and the elapsed time during the pursing operation. Curve B shows that the tension in the purse line when pursing begins before the net has settled, does not increase until after the first 2 min, and then it increases suddenly. In the first 2 min, the leadline is still sinking and there exists loose netting around the lead and purselines. This leads to the assumption that when using a deep seine, entanglements might occur in the early stages of pursing. Therefore, care is required before starting to purse. On the other hand, it is seen from curve A that, when pursing was begun after the net had sunk completely, the increase of tension was relatively uniform throughout the pursing period. This suggests that delaying the start of pursing until the net has sunk completely reduces the possibility of entanglement.

In order to overcome the disadvantage of waiting too long to begin pursing and yet ensure the seine has settled adequately, the sinking speed of the net is accelerated with weight. This is usually in the form of additional

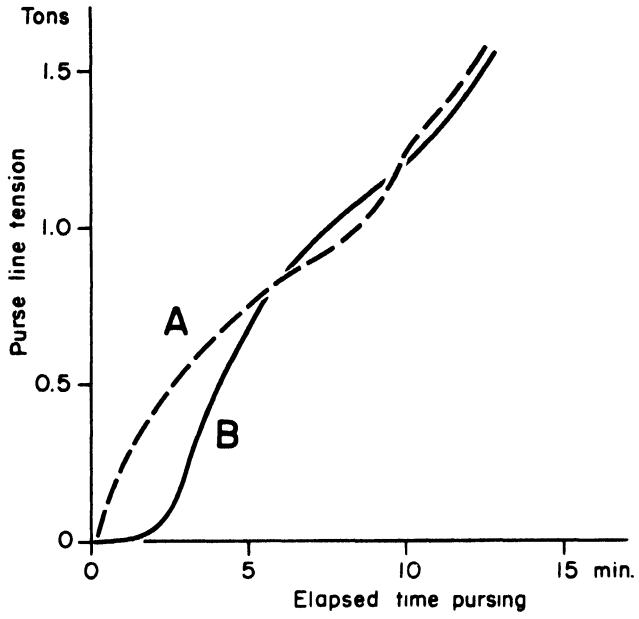

Fig 5. Relationship between the tension in the purseline during the pursing operation and the time involved. (A) *pursing commences after the net has sunk completely.* (B) *pursing commences while the net is still sinking*

weight on the leadline, particularly on the wing end or ends. Also, "tom-weights" of 200 to 500 kg are sometimes lowered along the purseline to reduce the opening between the two ends.

Mesh and twine size

These important factors are directly related to the size of the fish and quantities to be taken. Choice of too small a mesh unnecessarily increases costs and slows sinking speed. Too large a mesh results in loss of catch as well as in gilling. The latter is particularly costly in that large quantities of gilled fish are extremely difficult, time consuming, and costly to remove.

In Japan the following mesh and twine sizes are used in seines designed for the indicated species:

Species	*Mesh size (mm) (stretched)*		*Twine size (Total Tex)*	
	Bunt	*Body*	*Bunt*	*Body*
Pilchard		15	120	180
Sardine	30	40	540	630
Herring, mackerel	50	60	630	720
Tuna	90	180	1800	2400

Hanging ratio

The proper distribution of tension, the fishing depth, and the shape of the seine in operation are all directly related to the amount of slack used in hanging the netting to the framing lines. The slack varies in different parts of the seine. Generally, the hanging-in ratio

$$\frac{\text{excess netting}}{\text{stretched netting}} \times 100$$

is 20 to 30 per cent on the floatline and 10 to 20 per cent on the leadline. The smaller ratio on the bottom is to reduce the amount of excess netting and minimize the possibility of entanglement while pursing. This is more important in deep seines where the depth is 30 to 50 per

cent of the length. In shallow seines the hanging-in ratio is sometimes as great as 40 to 60 per cent since the entanglement problem is not as serious.

The hanging-in ratio is not distributed uniformly along the framing lines. It is common practice to use a larger ratio on the wing (or wings) for a distance of 12 to 16 per cent of the seine length in order to provide more fullness to the body. This serves to prevent or reduce fish escapement during the pursing operation.

Flotation and weight

The sinking speed of a seine has been found to be proportional to the square root of the apparent leadline weight (see fig 6). Therefore, it is normal to use as much

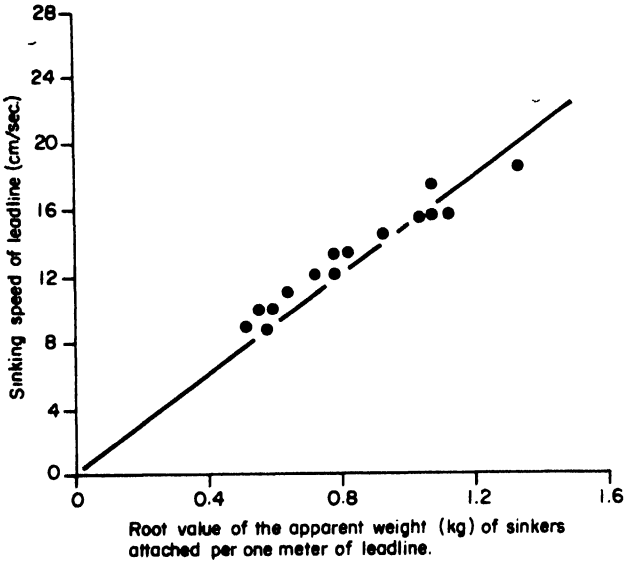

Fig 6. Relation between the sinking speed and weight (Iitaka 1965)

weight as practical. Excessive weight, however, results in gear damage, strain on hauling equipment and other handling problems. In Japan, the amount of weight used ranges from 1.0 to 2.5 kg per metre of leadline.

Flotation used on Japanese purse seines is about two to three times greater than the amount of weight used. The weight and flotation used on some seine designs is shown in Table 1.

TABLE 1. FLOTATION AND WEIGHT

Type	*Floatline length (m)*	*Stretched depth (m)*	*Buoyancy or weight per 1 metre length (kg)*	
			Floats	*Weight*
Mackerel	250	27	4.4	2.5
,,	190	14	3.2	1.5
Sardine	125	22	4.1	2.5
,,	115	22	4.1	2.0
,,	70	19	3.9	1.1
,,	100	17	4.0	1.9

SUMMARY OF EXPERIENCE

1. The heavier and harder continuous filament twine is preferable for purse seine netting because of its faster sinking rate factor.
2. Reef-knotted netting should be used in parts of the seine where extra load is expected and knotless netting used for the remaining parts.
3. Seines designed for surface schools should be of the long shallow type (depth 10 to 15 per cent of length) while seines for deeper swimming species must be relatively deeper (depth 30 to 50 per cent of length).
4. Generally, the netting twine size should be as thin as possible to reduce resistance and cost.
5. To reduce loss of catch, the hanging-in ratio of the seine should be relatively high.
6. Because excess hanging-in will result in loose netting near the bottom of the seine and cause entangling, it is customary to use a smaller ratio on deep seines than on shallow ones.
7. The amount of weight used ranges from 1.0 to 2.5 kg per metre of leadline. On deep seines the amount is increased at the ends to assist in avoiding entanglement during pursing.

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Purse Seine Materials in Japan

M. Nakamura

Materiel pour la fabrication des seines coulissantes au Japon

Les pêcheurs japonais de chinchards et de maquereau ont besoin d'une seine coulissante à plongée rapide afin d'éviter tout engagement dans les courants forts. On a ainsi été amené à utiliser une nappe de filet de masse spécifique élevée. C'est chlorure de vinylidène qui a la plus forte gravité spécifique (1,7) mais sa résistance à la rupture est médiocre, tandis que le nylon est résistant mais n'a qu'une densité de 1,14. Une combinaison de ces deux fibres permet d'obtenir un filet à plongée rapide (4,04 cm/seconde). Le térylène (polyester) utilisé dans les filets japonais sans noeuds (à fils retors) assure la meilleure résistance longitudinale et transversale. Les recherches se poursuivent sur l'utilisation de nombreux types de fibres synthétiques en vue d'améliorer les filets sans noeud Raschel. Diverses combinaisons de fils entrecroisés et de fils à boucles sont soumises à des essais en vue d'améliorer la résistance et la vitesse de plongée du filet sans noeud Raschel.

Materiales empleados en Japon para la fabricación de redes de cerco

La pesqueria japonesa del jurel y la caballa exige el empleo de redes de cerco de rápida inmersión, para evitar que se enreden en caso de fuertes corrientes. Eso ha movido a emplear materiales de elevado peso especifico. El cloruro de vinilideno es el material de mayor peso especifico (1,7), pero su resistencia a la ruptura es escasa; en cambio, el nilón, wás resistente, tiene un peso especifico de 1,14. La combinación de ambos hilos produce una red de inmersión rápida (4,04 cm/sec). El terileno (poliéster), empleado en las redes japonesas sin nudos (colchadas), es el material más resistente a la tensión longituninal y transversal. Se sigue investigando sobre el empleo de diversos tipos de fibras sintéticas para mejorar la red sin nudos Raschel. Se están probando varias combinaciones de hilos entrelazados y sin entrelazar para mejorar la solidez y la velocidad de inmersión de la red sin nudos Raschel.

IN the Japanese purse seine fishery, catches of bonito, tuna and sardines are exceedingly variable. Therefore, horse mackerel and mackerel are the two main species taken in seines. This is a night fishery using light attraction. Mackerel and horse mackerel purse seining requires several light boats, net boats for operating the seine and carriers for taking the catch to port. Fish finding echo sounders are used to observe fish concentrating under the luring lights. As fish schools are occasionally found in depths down to 200 m, the mackerel and horse mackerel purse seines must be deeper than other seines.

Strong and variable currents require careful choice of netting materials. The net must have a high sinking speed so that it is not carried away by the current and allow the fish to escape. This requires fine, heavy twine with a smooth surface.

Synthetic twine properties

Nylon filament is fine, strong and has a smooth surface, but its specific gravity is only 1.14, so it is rather light in water. Nylon is therefore not suitable for the bulk of the net and is only used for the bunt section. Among the various synthetic fibre materials, vinylidene chloride has the highest specified gravity of 1.7. However, it is not strong enough for large seine nets. A combination twine of nylon and vinylidene chloride, with vinylidene chloride for weight and nylon for strength, is used in some seine nets. Terylene (polyester) and vinyl chloride come second after vinylidene chloride with a specific gravity of about 1.4, but vinyl chloride is also too weak to be of use. The best solution seems to be a combination twine of terylene (polyester) and vinylon (polyvinyl alcohol) filaments (approximate specific gravity: 1.3) which is strong, can be made of fine thread, and is heavy enough in water to sink fast. Furthermore, netting made of this mixed twine withstands currents better.

TABLE 1. BREAKING STRENGTH OF DIFFERENT KNOTTED NETTING MATERIALS USED FOR JAPANESE MACKEREL AND HORSE MACKEREL PURSE SEINES

Type of netting	*Strength in longitudinal direction kg*	*Strength in transverse direction kg*
Vinyl filament twine 250d 15 ply	12.3	14.4
Terylene filament twine 210d 15 ply	13.2	13.6
Nylon filament 210d 6 ply / Vinylidene chloride 360d 6 ply (mixed twine)	11.3	10.6
Vinylidene chloride twine 250d 12 ply	14.5	14.5
Terylene filament twine 210d 12 ply	14.6	14.6

TABLE 2. SINKING SPEED OF DIFFERENT NETTING TWINES USED FOR JAPANESE MACKEREL AND HORSE MACKEREL PURSE SEINES

Twined thread	*Gravity*	*Dia of twine thread mm*	*speed cm/sec*
Vinylon filament twine 250d 15 ply	1.31	0.98	3.51
Tetolon filament twine 250d 15 ply	1.38	0.92	4.12
Nylon filament 210d 9 ply / Vinylidene chloride 360d 6 ply (Mixed 15 ply) (mixed twine)	1.38	0.96	4.04
Nylon filament twine 210d 15 ply	1.14	0.86	2.24

In the netting the conventional "English" knot and the Japanese (twisted) knotless are used for respective areas. The twisted knotless netting is lighter, requires no pre-stretching and has less tendency to be carried away by the current. Thus it is preferable to knotted netting.

Knotless Raschel netting

When (twisted) knotless netting breaks, it is difficult and costly to repair. Therefore the Raschel type knotless netting, which does not have this shortcoming, is coming into use. It is a netting with characteristics of both the knotted and the knotless (twisted) types. Raschel netting is made up of swing threads and looped threads, and there are a number of various combinations. The following are given as examples:

1. Swing threads and looped threads of the same type of fibre.

2. Swing threads and looped threads of different ratio, e.g. four swing threads and nine looped threads are combined to make a total of 13 in all, or a combination of six swing threads and six looped threads making 12 in all.

3. Swing threads and looped threads of different fibres such as nylon for the swing threads and Terylene for the looped threads, or vice versa.

4. Single or two to three interlacings for the connection.

By means of these combinations, the properties of the netting and its specific gravity can be adjusted to a certain extent.

The swing thread is gently curved while the looped thread has several loop patterns and is bent to 360°. Therefore, the net quality can be improved by combining the fibres according to their respective properties. At present, the combination of nylon and Terylene filaments appears to be ideal for Raschel netting. There are a number of combinations which are satisfactory, although the best combination has not been found yet. It seems that the breaking strength of the netting increases with the number of looped threads, however, if the number of swing threads is reduced too much the netting will tend to disintegrate when cut. Research is being continued to find the optimum combination and construction of Raschel netting for purse seines.

Synthetic Fibres used in Japan for Purse Seines and Trawls

Japan Chemical Fibres Association

Utilisation des fibres synthetiques au Japon pour les seines coulissantes et les chaluts

Les fibres synthétiques pour filets de pêche on été introduites au Japon en 1949. En 1968, les matériaux synthétiques ont presque complètement supplanté les fibres naturelles dans les filets de pêche, avec une production totale de 18.600 tonnes dont un tiers environ a été exporté. Pour les seines coulissantes, où il importe d'obtenir une vitesse de plongée élevée et une faible résistance hydrodynamique, on emploie de préférence le polyester et le polyamide. Dans le cas des chaluts qui réclament une grande résistance à l'abrasion et à la rupture le polyamide, employé à l'origine pour ces filets, est maintenant remplacé progressivement par le polyéthylène. Des tableaux donnent pour le Japon la production totale, les applications principales, les exportations, les caractéristiques, ainsi que les noms des fabricants et produits commerciaux des principaux textiles synthétiques employés dans les filets de pêche.

Fibras sinteticas utilizadas en el Japon para redes de cerco de jareta y de arrastre

La utilización de las fibras sintéticas para fabricar redes de pesca se introdujo en el Japón en 1949. En 1968, con una producción total de 18.600 toneladas anuales, los materiales sintéticos habían sustuido casi completamente a las fibras naturales en la fabricación de redes, exportándose un tercio aproximadamente de la producción japonesa. Para las redes de cerco de jareta las cualidades que se consideran de gran importancia son la rapidez de inmersión y la poca resistencia al agua, por lo cual los poliésteres y poliamidas son los materiales preferidos. Para las redes de arrastre se exigen fibras de elevada resistencia a la abrasión y a la rotura. Por diversas razones, las poliamidas, que en su principio se utilizaron para las redes de arrastre. Están siendo gradualmente sustituidas por el polietileno. Se exponen cuadros de la producción total, principal aplicación, cifras de exportación, características, nombres comerciales y productores de las principales fibras sintéticas usadas para la fabricación de las redes de pesca en el Japón.

FISHING nets of synthetic fibres first appeared in Japan in 1949. Initially, nylon (polyamide) was used in gillnets and in portions of surrounding nets, but since around 1952 it has been used in commercial gillnets for salmon and trout fishing in northern waters. Vinylon (polyvinyl alcohol) has been used for surrounding nets since 1951, and later vinylidene was introduced for large size setnets (traps).

The production of synthetic fibre fishing nets has continued to increase annually, and in 1956 surpassed the natural fibres. By 1957, synthetic fibres had accounted for 70 per cent of all fibres employed by the fishing net manufacturing industry.

Additional synthetic fibres such as vinyl chloride, polyethylene, polyester and polypropylene were introduced for fishing nets according to their characteristic properties. From 1964 all fishing nets were made almost entirely of synthetic fibres.

The success of synthetic fibre fishing nets, which has been described as a "revolutionary" event, has promoted the rationalization and modernization of fisheries and also contributed to the large-scale advancement of the Japanese fishing industry. In 1968, the Japanese production of synthetic fibre fishing nets was 18,600 tons of which 5,600 tons were exported.

Use of synthetics for nets

Table 1 shows that the 18,600 tons of synthetic fibre fishing nets produced in 1968 in Japan accounted for 98 per cent of the total production.

The following seven types of synthetics are used: polyamide, polyvinyl alcohol, polyethylene, vinylidene, polyester, polypropylene and polyvinyl chloride. About 5 per cent of all synthetic fibre nets are made of mixed twines, e.g. nylon mixed with polyvinyl chloride. There

TABLE 1. FISHING NET PRODUCTION IN JAPAN

Year	Grand total	Natural fibre nets total	Synthetic fibre nets total	Breakdown by fibre						
				Polyamide	Polyvinyl alcohol	Vinylidene	Polyvinyl chloride	Polyester	Polyethylene	Polypropylene
1960	10,596	2,344	8,252	3,639	3,194	709	528	93	99	
1961	11,295	2,006	9,289	4,134	3,567	715	409	167	297	
1962	11,732	1,346	10,386	4,726	4,040	509	364	187	560	
1963	12,965	1,061	11,904	6,976	2,320	689	448	416	967	88
1964	14,015	746	13,269	6,874	2,939	845	310	559	1,556	186
1965	16,236	567	15,669	8,944	3,345	827	279	482	1,715	77
1966	17,773	400	15,373	9,566	3,514	844	205	581	2,591	72
1967	18,765	381	18,384	10,283	2,933	869	183	407	3,569	150
1968	18,983	366	18,647	9,414	3,667	1,098	87	587	3,507	287

Source: Ministry of International Trade and Industry, Japan.

TABLE 2. UTILIZATION RATIO OF SYNTHETIC MATERIALS FOR FISHING NETS IN JAPAN (%)

	Setnets	Purse seines	Trawl	Gill nets	Lift nets	Laver nets	Culture nets	Other nets	Total
Polyamide	4	27	7	43		4	2	13	100
Polyvinyl alcohol	12	17	8	5	5	35	9	9	100
Vinylidene	80	3	5	5			5	2	100
Polyvinyl chloride	69	5	4				9	13	100
Polyester	20	72	4	2			1	1	100
Polyethylene	10	10	46	2	6	9	7	10	100
Polypropylene				92			7	1	100

Source: Japan Chemical Fibres Association

are more than ten different mixtures, which may consist of up to four different materials.

Synthetic net materials are naturally selected for different fishing gear according to their characteristic properties. The main application is at present as follows (see also Table 2):

Polyamide (nylon)	Gillnets (salmon and trout), purse seines (sardine and tuna)
Polyvinyl alcohol	Purse seines (horsemackerel, mackerel and tuna) and lavernets
Polyethylene	Trawls
Vinylidene	Setnets (yellowtail), liftnets (mackerel and pike)
Polyester	Purse seines (horsemackerel and mackerel) and setnets
Polypropylene	Entangling nets (crabs)
Polyvinyl chloride	Setnets and liftnets

EXPORT DEVELOPMENT

In terms of fishing net production and variety of synthetic fibre materials, Japan is the leading and most advanced country in the world.

Although in recent years some developing countries have increased their domestic production of fishing nets and have further progressed to export markets, Japan's fishing net exports presently account for 30 per cent of total production (Table 3). The nets, after passing rigid quality control tests, are shipped worldwide to more than 100 foreign countries.

TABLE 3. FISHING NET EXPORTS OF JAPAN (1968)

	Unit: tons
Natural fibre nets, total	136
Synthetic fibre nets, total	5,427
Polyamide	4,367
Polyvinyl alcohol	233
Vinylidene	2
Polyvinyl chloride	2
Polyester	35
Polyethylene	438
Polypropylene	32
Polyamide/polyvinyl alcohol, mixed yarns	77
Polyamide/vinylidene, mixed yarns	136
Other mixed yarns	105
Grand total	5,563

Source: Japan Fishing Net Inspection Institute Foundation.

SYNTHETIC FIBRES FOR PURSE SEINES

The most essential requirements for purse seines are: high breaking strength, rapid sinking and water-shedding capacity. The purse seine is hauled in by a net hauler or power block and therefore high breaking strength is required to avoid breakage. Since the net must envelope a school of fish quickly, it should be able to sink rapidly before being swept away by the current. The net, after being hauled in, must shed water easily. Polyamide, polyvinyl alcohol and polyester netting yarns best meet these requirements.

For sardine purse seines, polyamide predominates, while for mackerel and horsemackerel purse seines, polyvinyl alcohol or mixed polyamide/polyvinyl alcohol twines or polyester may be used. In the case of polyvinyl alcohol, continuous filaments are rapidly replacing the staple fibre used earlier.

In recent years, polyester knotless nets of twisted and Raschel type are much in evidence and are being increasingly used. For tuna purse seines, nylon and vinylon knotless netting predominates. Mixed yarns of high density polyethylene and polypropylene with polyamide are now being used in limited quantities.

The following properties of the three main synthetic materials used for purse seines are considered particularly important:

Polyamide: Especially high breaking strength and easy for mechanical net braiding (elongation and shrinkage degrees are most suitable)

Polyvinyl alcohol: Low current resistance and high sinking speed, also high weather resistance

Polyester: High sinking speed, superior dimensional stability and low current resistance.

Table 4 gives the characteristics, producers and trademarks of synthetic fibre yarns used for Japanese purse seines.

SYNTHETIC FIBRES FOR TRAWLNETS

The most important properties of a trawlnet are:

Especially high abrasion resistance to withstand chafing on the bottom and on board

Low towing resistance to enable the largest possible net size

High breaking strength

Of all the synthetic fibres which have been introduced in rapid succession since 1950—polyamide, polyethylene, polyvinyl alcohol, polyvinyl chloride—the first two are considered the most suitable and at present predominate in the manufacture of trawlnets. Polyethylene, which was introduced later than polyamide, has now surpassed it as a result of rapidly increasing popularity. Both materials have great abrasion resistance but polyamide has higher breaking strength, whereas polyethylene's specific gravity is lower (it floats). Table 5 provides further information about these two fibres.

TABLE 4. SYNTHETIC FIBRES FOR PURSE SEINES IN JAPAN

Material	*Kind of yarn*	*Size of yarn (denier or count number)*	*Producers*	*Trade marks*
Polyamide	Multifilament	210d/24F 420d/48F 630d/72F 840d/96F	Toray Industries, Inc. Unitika Ltd. Teijin Ltd. Asahi Chemical Industry Co., Ltd. Toyobo Co., Ltd.	Toray Nylon "Amilan" Unitika Nylon Teijin Ltd. Asahi Kasei Nylon Toyobo Nylon
Polyvinyl alcohol	Multifilament Staple yarn	250d/36F 500d/72F 20s	Kurashiki Rayon Co., Ltd. Unitika Ltd.	Kuralon, Kuremona-F Unitika Nylon
Polyester	Multifilament	250d/24F 250d/32F 500d/48F 500d/64F	Teijin Ltd. Toray Industries, Inc. Kurashiki Rayon Co., Ltd.	Teijin Tetoron Toray Tetoron Krafter-F
Vinylidene	Multifilament	360d/3F 720d/6F 1080d/9F	Asahi-Dow Ltd. Kureha Chemical Industry Co., Ltd.	Saran-N Kurehalon
Polyethylene	Monofilament	200d 400d	Mitsui Toatsu Chemicals, Inc. Kanegafuchi Spinning Co., Ltd. Ube-Nitto Kasei Co., Ltd. Kureha Chemical Industry Co., Ltd.	Hi-Zex Kanelight Sunline Ethylon
Polypropylene	Monofilament	400d	Mitsui Toatsu Chemicals, Inc.	Pro-Zex

TABLE 5. SYNTHETIC FIBRES FOR TRAWLNETS IN JAPAN

Material	*Kind of yarn*	*Size of yarn (denier or count number)*	*Producers*	*Trade marks*
Polyethylene	Monofilament	200d, 380d, 400d	Mitsui Toatsu Chemicals, Inc. Kanegafuchi Spinning Co., Ltd. Ube-Nitto Kasei Co., Ltd. Kureha Chemical Industry Co., Ltd.	Hi-Zex Kanelight Sunline Ethylon
Polyamide	Multifilament	210d/24F 420d/48F 630d/72F 840d/96F	Toray Industries, Inc. Unitika Ltd. Teijin Ltd. Asahi Chemical Industry Co., Ltd. Toyobo Co., Ltd.	Toray Nylon "Amilan" Unitika Nylon Teijin Nylon Asahi Kasei Nylon Toyobo Nylon

Ropes for Purse Seines and Bottom Trawls

K. Honda

Cordages pour sennes coulissantes et chaluts de fond

La production japonaise de cordages s'est accrue de 3,5 pour cent par an pendant les cinq dernières années. Le nombre de types de matériaux utilisés pour la fabrication des cordages en fibres naturelles a diminué, tandis que celui des fibres synthétiques a augmenté. Si l'on appelle T la résistance à la traction et D le dia mètre de corde, nous avons l'équation $T = KD^2$ dans laquelle K est une constante. La valeur de K varie en fonction du type de matériau utilisé pour les cordages. En ce qui concerne la récupération d'élasticité, que l'on vérifie au moyen de tests renouvelés de chargement et de déchargement, le cordage en nylon (polyamide) est d'une meilleure qualité que les autres. Quant aux tests d'abrasion (meule), les cordages en polypropylène monofilament ou en polyester ont une résistance supérieure. Le cordage en vinylon a un coefficient de friction calculé plus faible que le cordage en nylon à l'état humide. La résistance utile minimum des cordages pour l'engin de chalutage devrait atteindre environ 50 pour cent de la résistance initiale; ce pourcentage doit être accru proportionnellement au tonnage du bateau de pêche.

Cabos para artes de cerco y redes de arrastre bentonicas

En el Japón, la producción de cabos ha aumentado en los últimos cinco áños a razón de casi un 3,5 por ciento anual. La variedad de materiales empleados para la fabricaccion de cabos de fibras naturales ha disminuido, mientras ha aumentado el de fibras sintéticas. Denominando respectivamente T y D la resistencia a la tracción y el diámetro del cabo, tenemos que $T = KD^2$, donde K es una constante cuyo valor varía según el material empleado en el cabo. Por lo que se refiere a la recuperación elástica, que se comprueba suspendiendo y retirando repetidamente pesos de un cabo, el de nilón (poliamida) es de major calidad que los demás. En las pruebas de resistencia al desgaste (muela), el cabo monofilamento de polipropileno y el de poliéster han resultado las más resistentes. El cabo de vinilón mojado tiene un coeficiente de resistencia al roce inferior al de nilón, también mojado. La resistencia mínima necesaria para utilizar un cabo en artes de arrastre debe ser igual, aproximadamente, al 50 por ciento de su resistencia inicial, y esa proporción ha de aumentarse según el tonelaje de la embarcación.

THE total amount of rope produced in Japan in 1969 was about 53,000 tons. It has increased every year by an average of 3.5 per cent for the past five years. About 65 to 70 per cent of the production is used for fishing gear while about 4,000 tons are exported.

The construction materials of ropes used for fishing gear are manila hemp, sisal, straw, nylon, polyester, polyvinyl, polyvinylidene chloride, polyethylene and polypropylene. For the past several years, the use of different kinds of natural fibres in rope has decreased while the use of synthetic fibres has increased. Almost all kinds of synthetics fibres produced in Japan have been used for making fishing gear.

PROPERTIES OF ROPES IN PURSE SEINE AND BOTTOM TRAWL GEAR

Dimensions of ropes used for floatline, leadline, headline, footrope, warp and ribline of bottom trawls and purse seines are shown in Table 1. The special properties of some ropes, as well as the costs, contribute to the fisherman's decision to adopt them for his particular needs.

Tensile Strength

If the diameter and tensile strength (dry) of ropes are denoted by D and T respectively, and the diameter is under 30 mm, the relation between D^2 and T can be expressed as:

$$T = kD^2$$

where k is a constant number. The values of k of various ropes are shown in Table 2 (Honda, 1969). Tensile strength of rope varies by the values of the constant k and k has a tendency to increase in value as the thickness of rope decreases.

Under wet conditions, the tensile strength of natural fibre ropes increases by about 15 to 20 per cent. Whereas that of synthetic fibre ropes which absorb water decreases by about 15 to 20 per cent under wet conditions, while those which do not absorb water maintain almost the same values.

TABLE 1. DIMENSION OF ROPES USED FOR PURSE SEINE AND BOTTOM TRAWL

Kind of fishing gear		*Material*	*Construction*		*Remarks*
Bottom trawl warp	Large trawl	Manila, PP (Polypropylene) spun	3 strands CPR*	45–54 mm	f = filament rope cross section *3 strands compound rope (CPR)
			3 strands CBR**	45–54 mm	
	One-boat medium trawl	Manila, PP spun Polyester multifilament, PE (Polyethylene) monofilament, Manila, and PP mixed	3 strands CPR 6 strands CPR***	20–40 mm	
			3 strands CBR		**3 strands combination rope (CBR)
Purse seine, floatline, leadline		Vinylon spun, multifilament, PE monofilament, PP spun, Polyester spun	3 strands 8 strands	16–24 mm	***6 strands compound rope The use of these types of rope has been increasing

TABLE 2. VALUES OF TENSILE STRENGTH COEFFICIENT k

Material and size of rope	*Nylon 1,260D*	*Vinylon 1,500D*	*Tetoron 1,000D*	*Polyethylene 600D*	*Polypropylene 680D*	*Polychloride 450D*	*Manila*
Value of k	18.2	14.5	13.9	9.77	12.4	6.73	6.28

Generally, if the diameter of the rope is known, the tensile strength can be estimated for practical use by the above equation and Table 2.

Elongation and elastic recovery

While the fishing gears are in operation, the load factors are always changing. Because of this it is important to know how much the ropes stretch or shrink after use. The degree of regaining its original length after loading is called the elastic recovery. It is not easy to keep the net in proper form when ropes have a poor elastic recovery. Elongation of rope depends on size, the material used and its construction. Good quality ropes have small elongation to weight ratio and large elongation at break. The breaking elongation of ropes varies considerably due to the different kinds of material used and type of construction.

The following two experiments were done for manila, polyethylene, vinylon and nylon ropes with a diameter of 5 mm, after being soaked in water for more than 24 h (Ozawa, 1964).

1. A load equivalent to 20 per cent of the wet tensile strength of the ropes was applied for a duration of 5 min. The elastic recovery of the rope was examined after unloading.
2. The load was increased by 10 kg and the hysteresis-loops were drawn during the experiment. From these figures, elastic recovery for every load was investigated.

Results obtained (fig 1) show the decrease in elongation of manila, vinylon and polyethylene as having the same characteristics, while nylon ropes decrease suddenly immediately after unloading although reduction of elongation is small with the elapse of time. Elongation in the initial stage is large for vinylon rope, whereas reduction with the elapse of time is small.

For various ropes with 12 mm diameter, a load equivalent to 50 per cent of their tensile strength was applied for 5 min. After unloading, rope elongation with regard to elapsed time was examined (Hara, 1969). The nature of elongation with the elapse of time shows the same tendency but differs in the amount of elongation. This difference is probably caused by the combination of the difference of material and the difference of twist of the ropes. Polyethylene rope was found to be better than others in elastic recovery under light load followed by nylon, manila and vinylon ropes (fig 2). But as the weight of the load increases, nylon rope is the best, followed by polyethylene, vinylon and manila ropes.

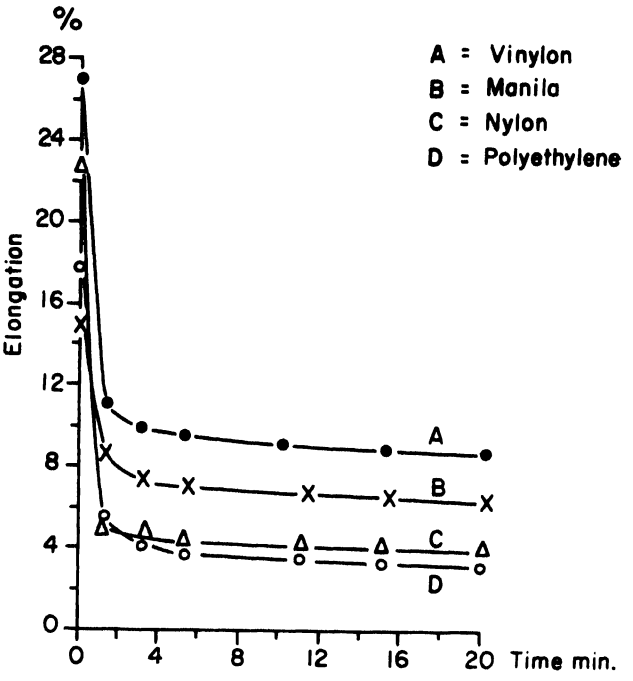

Fig 1. Relation between time and elongation

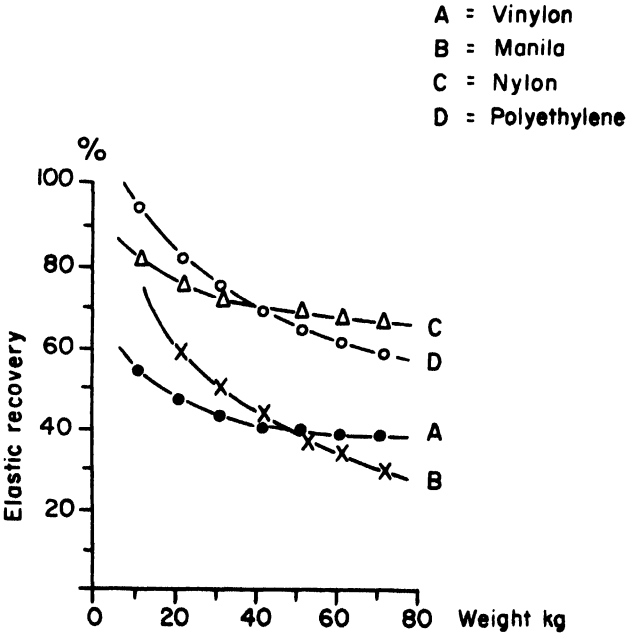

Fig 2. Relation between weight and elastic recovery

Abrasion resistance and coefficient of friction

Ropes lose strength gradually during fishing due to chafing on the bottom and on the rail, deck etc., of the vessel. Resistance against such abrasion was tested on a machine consisting of a slowly-rotating cylindric grinder and a crank with a stroke of 220 mm (Hara, 1969). The rope sample was attached with one end to the crank, led over the grinder and kept tight by a 10 kg weight attached

to the other end. To obtain uniform abrasion, the rope was turned on the grinder every third stroke and kept wet. The testing speed was 50 strokes per minute. The tests revealed that polypropylene monofilament rope and Tetoron (polyester) rope have good anti-abrasion qualities.

In testing the durability to abrasion in 500 runs, with nylon, polyethylene and manila ropes, manila rope was found to possess the best durability although polyethylene and nylon ropes are almost equal.

The author also calculated the coefficient of friction using the data obtained by measuring the different frictional forces for different kinds of ropes wound around a drum of 54 cm diameter, with a smooth surface finished by a lathe (The Fisheries Science, 1964). A load of 40 kg (T_1) was attached to one end of the rope sample which was wound around the drum while the other end was attached to a tension meter. As the drum moved, slip occurred and the tension (T_2) of the beginning of the slip was measured. If μ is the frictional coefficient and θ the angle of contact between the drum and the rope, the following equation is obtained:

$$T_2/T_1 = e^{\mu\theta}$$

and from this equation:

$$\mu = \log \frac{T_2}{T_1} \times \frac{1}{\pi \log e}$$

when $\theta = 180°$

The values of μ calculated from the equation are shown in Table 3. The value of μ of vinylon rope is smaller when wet than when dry. On the contrary, nylon rope gave bigger values of μ when wet than when dry. Subsequently, it seemed that vinylon rope slipped easier than nylon rope in water, and probably the value of μ decreased gradually according to the number of turns on the drum which increased the contact between the ropes.

TABLE 3. COEFFICIENT OF FRICTION (μ)

	Dry				*Wet*			
Number of turns	2	3	4	5	2	3	4	5
Vinylon Spun 45 mm		.20	.19	.18		.20	.18	.17
Nylon multi-f 50 mm	.18	.19	.18		.30	.27	.23	

f = filament.

Safety limit of strength for utility of rope

Minimum strength permissible for ropes used in fishing gear was determined empirically by the fishermen with regard to the peculiarities of the individual fishing grounds. Various used warps, headropes and footropes were gathered for test purposes from 11 fishing boats (35 to 85 tons, headrope lengths 48 to 79.5 m) operating in an area around Hokkaido and Honshu. In order to examine the minimum strength, the relation between the ratio of strength of rope (T) and its initial strength (T_0) and the total number of months it had been used are shown in fig 3. From this figure the minimum ratio permissible derived is about 50 per cent of the initial breaking strength (Honda, 1960).

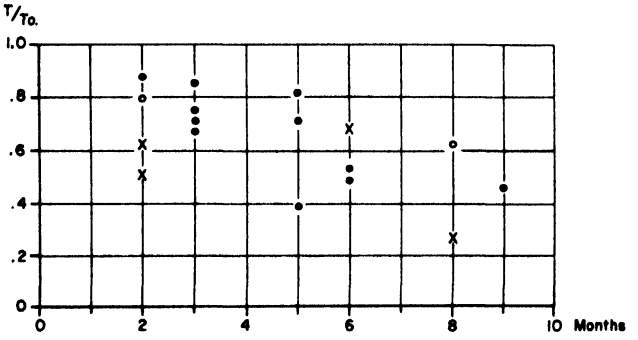

Fig 3. Relation between reduction in breaking strength of ropes and duration of use

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Development and Testing of the Hybrid Tuna Purse Seine

R. E. Green, J. E. Jurkovich, B. Petrich

Mise au point et essais de la seine coulissante hybride a thon

Les échecs observés dans un pourcentage élevé des coups de seines à thon effectués par les Américains sont à l'origine du projet d'étude d'une seine coulissante à thon expérimentale. La mise au point du projet a été réalisée au moyen de modèles à l'échelle. La fabrication et les essais en grandeur réelle de la seine sont décrits. Ce filet diffère des seines à thon américaines classiques sur les points suivants: (1) alèze plus légère, (2) coefficient d'armement plus faible, (3) ailes d'extrémités coupées en diminution, (4) assemblage des bandes de fond avec reprises de mailles progressives, (5) ralingues de flotteurs et de plombs d'égale longueur, (6) anneaux de boursage en bout du filet et (7) fixation des anneaux de coulisse en retrait des extrémités. Cette combinaison fournit une seine qui plonge plus vite, pêche plus profondément, et présente une meilleure configuration générale que les seines à thon classiques. On est venu à bout des difficultés apparues dans la manoeuvre et dans le sauvetage des dauphins capturés avec les thons en éliminant la particularité d'assemblage avec reprises de mailles.

Construcción y ensayo de una red de cerco híbrida para la pesca del atun

Un porcentaje elevado de los lances efectuados en la pesqueria de atún norteamericana con redes de cerco de jareta no tiene éxito. Esto indujo a realizar un proyecto experimental con redes atuneras de cerco de jareta. El desarrollo del disèño se efectuó mediante el empleo de modelos a escala reducida. Se describe la construcción y ensayo de redes de cerco de tamãño natural. Estas redes de cerco se diferencian de las que normalmente se fabrican para tal fin en los Estados Unidos enque tienen: (1) paños más ligeros; (2) un menor coeficiente de armadura; (3) los extremos de las alas en disminución; (4) incremento de la armadura con el empleo de cadenetas inferiores que van en disminución; (5) relinguas superior e interior de iqual longitud; (6) anillas en los extremos; (7) las anillas principales de la jareta colocadas en los extremos de la red. Esta combinación produce una red de cerco que se sumerge con más rapidez, pesca a mayor profundidad y da una mejor configuración total que las redes de cerco normales para pescar atún. Las dificultades que supone su manejo y la recogida de las marsopas capturadas junto con los atunes se resolvieron eliminando el empleo de cadenetas reducidas. Los ensayos de pesca indicaron que aumentaran las posibilidades de éxito utilizando esta nueva red de cerco.

COMPARATIVELY little technological research has been done on purse seines despite the fact that they take increasingly larger portions of the world's catch of fish. Observed differences in performance and construction of existing purse seines and rates of success (percentage of sets catching at least ½ ton) of purse seine sets for tuna in the eastern tropical Pacific Ocean as low as 50 to 60 per cent led to a project to improve the design of these tuna purse seines (Ben-Yami and Green, 1968). This project is here summarized.

DESIGNING HYBRID PURSE SEINE

It was decided to work on a seine design intended for "school fish", as opposed to one intended for tuna associated with porpoise ("Porpoise" refers to tuna associated with porpoise (Perrin, 1969) as opposed to pure schools of tuna. In porpoise fishing, the net is set on a porpoise school for the tuna found beneath them. If the set is successful, the problem is then to separate porpoise from tuna).

The experimental phase of the study (Ben-Yami and Green, 1968) consisted of testing two model purse seines underwater. The first, Model I, was a 1:25 scale model of the standard California tuna purse seine. After testing, it was reworked to form Model II in an effort to produce a better combination of performance characteristics. This experimental approach was based on the assumption that should two different seines be scaled down in a uniform manner, the main differences in performance between the models would parallel those between the full-scale nets. In Model II, the main alteration consisted of varying hanging coefficients (k_h) (hanging coefficient k_h: ratio of stretched length of adjacent sections of webbing or ratio of length of line to stretched length of adjacent webbing (Ben-Yami. 1959)), from 0.7 at the top to 0.9 at the bottom (see Table 1), introducing gavels (vertical lines at the net ends, which can be pursed separately), and tapering the body. Total size, ballast and other common components were not changed.

TABLE 1. CONVERSION OF HANGING COEFFICIENT (K_h) TO "HANG-IN" PERCENTAGE

k_h	*Hang in* (%)
0.62	60
0.7	43
0.75	33
0.78	28
0.79	27
0.8	25
0.83	20
0.85	18
0.86	16
0.87	15
0.9	11
0.91	10

Comparative tests indicated that Model II sank at twice the rate of Model I and offered a smaller escape opening at its ends while retaining the acceptable pursing performance of Model I. In addition, the working depth was less sensitive to horizontal strains observed on the netting in Model II than in Model I.

Results indicate that k_h is probably the most important design variable affecting sinking speed, area encircled, and pursing performance. Low k_h allows a faster sinking rate and greater area of encirclement during later stages of the set. It also causes the leadline to rise earlier during pursing. High k_h gives the opposite effects. Many other

factors affect these and other performance characteristics such as weight of ballast, size of mesh, and size of twine.

The above mentioned factors were considered in the final design and manufacture of a hybrid purse seine, which essentially is a scaled-up Model II combined with design features from various other purse seine types.

HYBRID TUNA PURSE SEINE IN COMPARISON WITH U.S. TUNA PURSE SEINE

The main features of the hybrid seine which differentiate it from existing U.S. tuna seines are:

1. Lighter netting
2. Low k_h
3. Tapering of the lower four strips of netting
4. Incremental "hang-in" in the lower four strips
5. Floatline and leadline equal in length
6. Gavels or "breastlines" used at both ends
7. No main rings or bridles connected to the first and last 35 fm of seine.

Lighter Netting

The typical U.S. tuna seine is made up of seven or eight strips, each 100 meshes deep (MD) laced in horizontally, which extend full depth to the extreme ends of the seine. The ends are then baited to a short, 125 mesh long by 15 MD, border, which in turn is laced to a metal triangle. No tapers are used (fig 1, McNeely, 1961).

The hybrid seine (fig 2) was constructed of 100 per cent nylon netting of knotless braided construction. The main body of netting was laced into horizontal, 100 MD strips, except for the two bunts, which were laced in vertically to attain the maximum strength. Strength is needed at that point, as the maximum strain occurs there when drying the bunt prior to brailing. The maximum strength is achieved "with the run" (longitudinal) in knotless netting, which is opposite of that in knotted netting.

The top and bottom borders are 5 in. stretched mesh (M) 10-½ MD #54 (4,022 Tex) nylon netting and 5 in. M, 10-½ MD, #72 (5,512 Tex) nylon netting is used in the gavels at the extreme ends. Twine sizes were increased to #36 (2,706 Tex) and #42 (3,543 Tex) in the 100 fm (183 m) forward of the bunts (rolling strips). The top strip is #36 (2,706 Tex) because this is the area of greatest wear. The four strips in the bottom portion were reduced to #24 (1,984 Tex) twine. The centre bunt is #54 (4,022 Tex) and the main bunt is #60 (4,377 Tex). The netting requirements were planned with the idea of keeping the twine sizes as light as possible, while strengthening the areas of greater strain such as the perimeters and the rolling strips adjacent to the bunts.

Netting twine presently used in conventional tuna seines is rarely lighter than #42 (3,543 Tex) except in the rolling strips, where #54, #60, and #72 (4,022, 4,377, and 5,512 Tex) are used. The bunts and border strips are made up of #84, #96, and #120 (7,440, 9,921, and 11,023 Tex) nylon. The twine sizes used depend on vessel size and its ability to handle bulk and weight and stacking space available.

The lightness of netting and the mesh sizes, together with the weight of leadline, play a direct role in the sink rate of the seine. Thus, to enhance the sink rate the seine should be constructed of the lightest netting possible.

Lower k_h and Tapers

Standard tuna seines are hung using a k_h of 0.87 to 0.91. The k_h used depends on individual preference and varies from vessel to vessel. The body strips are usually laced together at k_h 1 except the seams which are laced to the float and leadline border strips. A common practice is to lace one or two meshes of extra netting every 2 fm to the border strips. This is done primarily because it is assumed that the heavier border strips shrink slightly more than the adjacent lighter strips. Should this premise be true, then the lacing ratio of all seams after shrinkage should be about 1:1.

The hybrid seine (fig 2) was hung at a k_h of 0.85 for the first 35 fm (64 m) at each end, followed by k_h = 0.80 for the next 15 fm (27 m). The extra tightness in the ends takes some of the strain from the leadline and floatline and allows easier hauling. The centre portion was hung at k_h = 0.75 with the exception of the centre bunt, which was 0.78. This was done to cut down undue bagging at the bunt, thus making it easier to "dry up" the seine for brailing.

The lower four strips (100 MD each) of the hybrid seine were started and ended with two bar, one mesh tapers (fig 2). Each taper was approximately 10.5 fm (19.2 m) long graduating from one mesh to 100 MD over this span. This deepened the hybrid seine by 400 meshes over a taper span of 42 fm (77 m) on each end. These tapers worked extremely well and are considered one of the best features of the new seine. Tapers eliminate unnecessary accumulations of netting at the ends of the seine as well as enabling maximum fishing depths precisely where they are most needed. The elimination of netting at the ends is also a great aid to drying up the catch prior to brailing. For further discussion of tapers the reader is referred to Jurkovich (1967).

An incremental "hang-in" was used in the lower four strips (100 MD) of the hybrid seine. The fifth strip was laced to the sixth strip at the rate of 30 meshes of the bottom of the fifth strip to 29 meshes of the top of the sixth strip (fig 2). The other lower strips were laced together in the same manner. This resulted in a progressive .967 reduction in each of the lower four strips which in turn reduced the k_h at the leadline to approximately 0.86.

Float- and leadlines

The hybrid seine was hung to a chain leadline 450 fm (823 m) long. This leadline was made up of 105 fm (192 m) of ⅜ in (9.5 mm) dia galvanized proof coil chain at each end adjoining two 92 fm (168 m) pieces of 7/16 in (11.1 mm) dia chain with 66 fm (121 m) of ½ in (12.7 mm) chain in the centre portion (fig 3).

The floatline was also 450 fm (823 m) long. Its centre was ⅝ in (15.9 mm) dia, three strand nylon rope 374 fm (684 m) long spliced to two 26 fm (48 m) pieces of ¾ in (19.0 mm) dia three strand nylon and was terminated with two 17 fm (31 m) pieces of ⅞ in (22.2 mm) dia three strand nylon rope. All lines were cut into shorter lengths for easier stringing of floats.

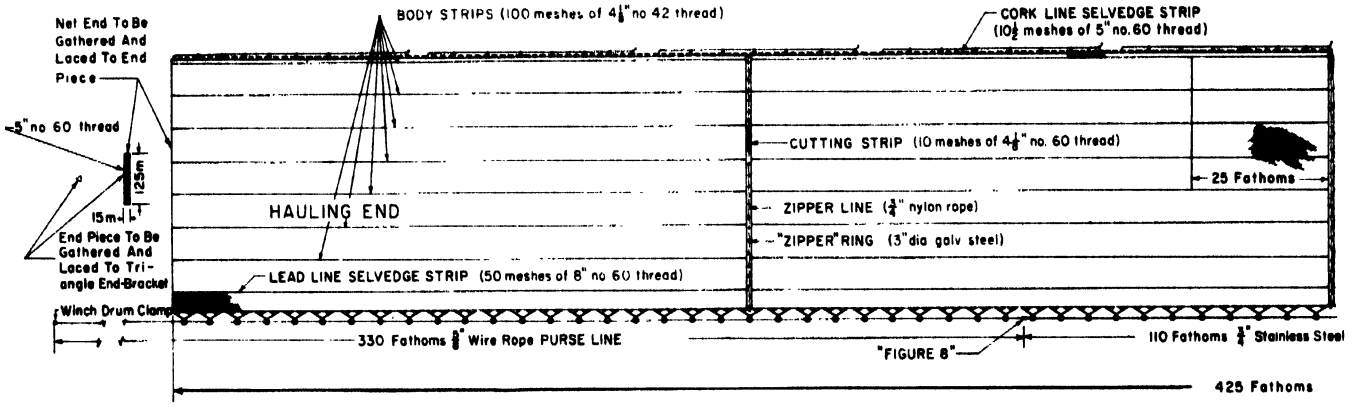


Fig 1. Standard U.S. tuna purse seine constructed of seven or eight strips each 100 meshes deep, M =

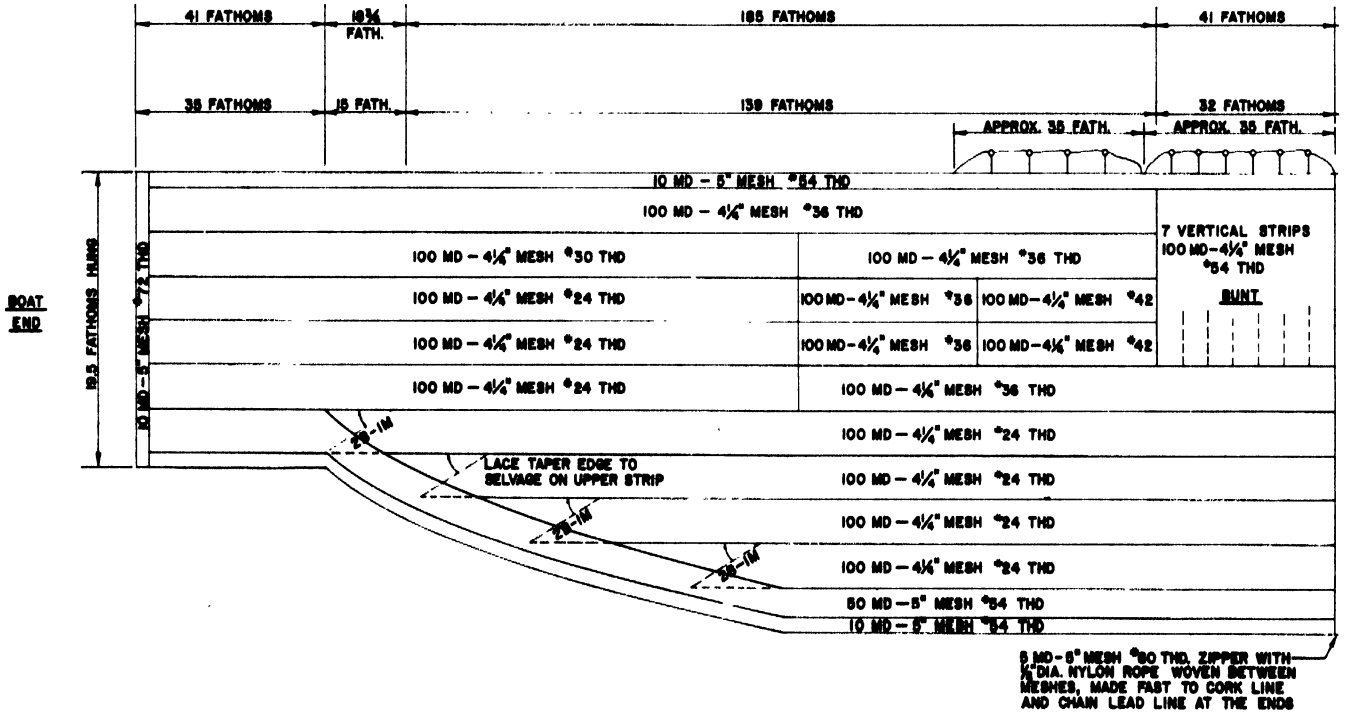
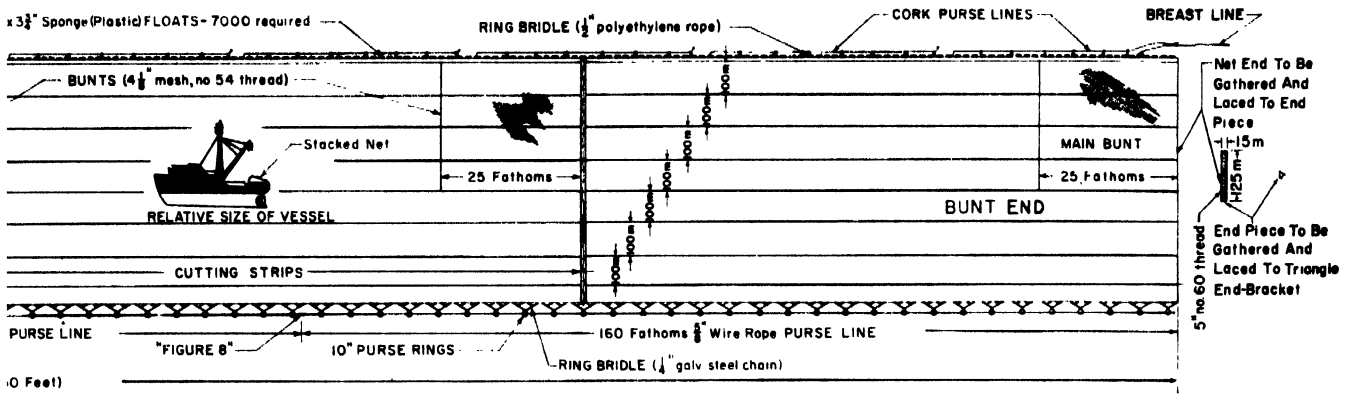


Fig 2. Hybrid tuna purse seine
M = meshes; MD = meshes deep; FATH = fathoms;



:h are laced in horizontally, and extend at full depth to the ends of the seine (McNeely 19
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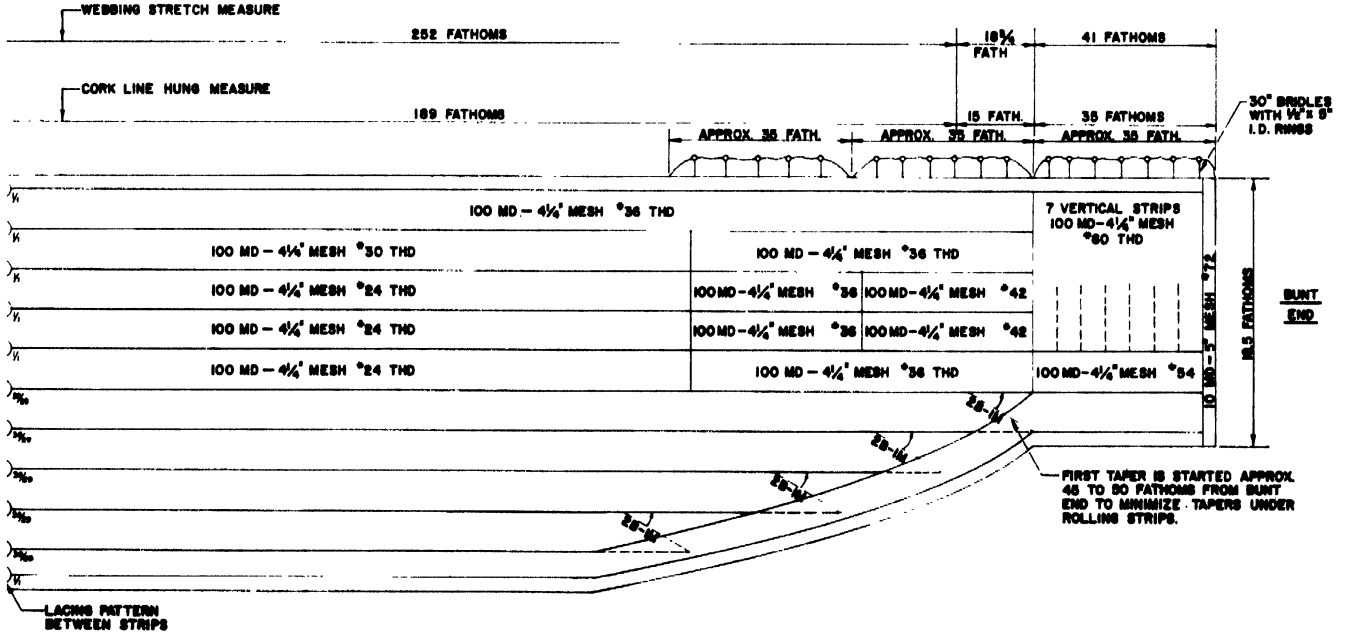

:tting and accessories.
D = thread; B = bar; ID = inside diameter

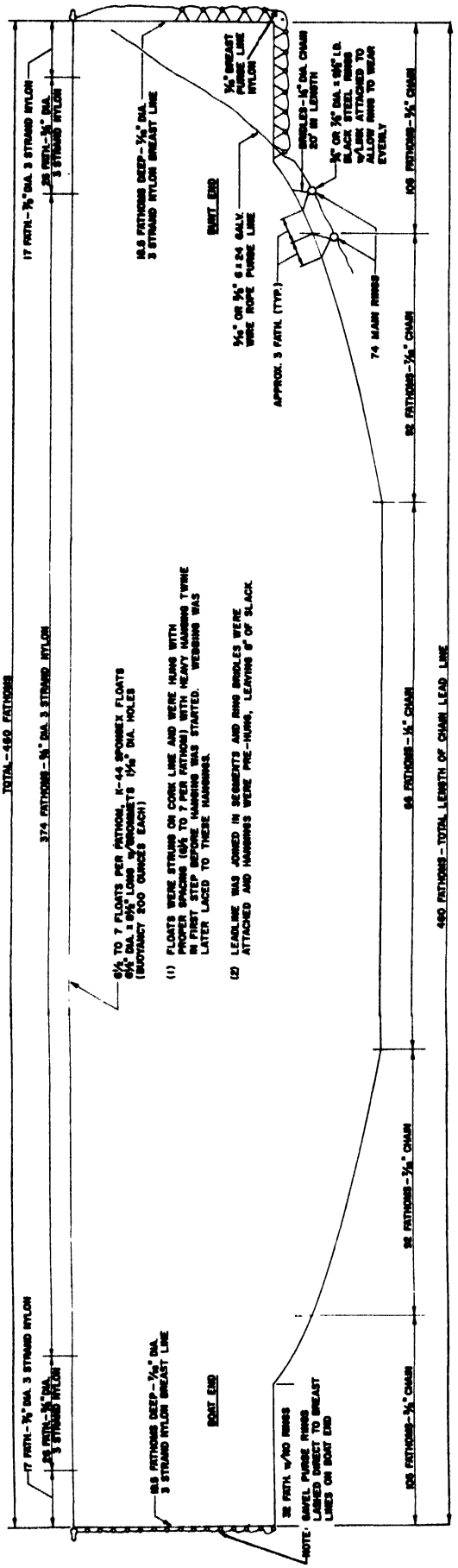

Fig 3. Hybrid tuna purse seine

U.S. tuna seines are usually hung with leadlines 5 to 10 per cent shorter than the corklines. This has been an accepted practice for tuna and salmon seines for many years. Salmon seiners in the Pacific Northwest and Alaska continue the 10 per cent shorter leadline practice because they feel it aids in the holding of salmon, when their seines are held open and towed with the power skiff and vessel. Although U.S. tuna seiners do not tow their seines, the 10 per cent shorter leadlines are possibly a leftover from these early ideas of seine fabrication.

Gavels and setback

The typical U.S. tuna seine has no gavels. The ends are baited to short border strips of netting 125 meshes long by 15 meshes deep, which in turn are laced to terminal stainless steel triangles. The full seven or eight strips are carried to the extreme ends of the seine, and the abrupt baiting of netting gives the appearance of gavels. However, this creates a large gap in the net wall under the vessel, leaving a possible escape route for encircled tuna. To help prevent this loss of fish, gavels or breastlines were installed at opposite ends of the hybrid seine. The bunt end was made 18½ fm (34 m) deep, and the back end was hung 19½ fm (36 m) deep. Small galvanized rings ½ in (12.7 mm) rod dia by 4 in (10.2 cm) inside dia (I.D.) were lashed to the upright breastline, made from $\frac{7}{16}$ in (11.1 mm) dia three strand nylon rope (fig 4). In order to distribute hauling strain on the netting more evenly, 32 meshes of the top of the gavel selvage strip are bunched and hung to the steel triangle or end piece (fig 5).

The hybrid seine was rigged without main purse rings or bridles for the first and last 35 fm (64 m). To fill this gap, a series of galvanized steel rings (½ in (12.7 mm) × 6 in (15.2 cm) I.D.) with nylon rope bridles were required. These rings were lashed under the end bunt with a ½ in (12.7 mm) dia nylon breast-purseline to purse the bunt end while the main purse rings are being drawn to the surface. This was done to permit the main wire purselines to work independently of the gavels, thereby permitting them to hang perpendicularly from the davit. An 18.5 fm (34 m) curtain of netting is thus formed directly under the boat.

On conventional U.S. tuna seines the ring bridles are connected the entire length of the chain leadline or with very little setback.

PHYSICAL PERFORMANCE

Based upon the performance of the scale Model II (Ben-Yami and Green, 1968), a prediction was made of the range of sinking performance of the hybrid purse seine at mid-net prior to start of pursing. This range was graphically compared to the measured sinking range of a conventional tuna purse seine (fig 6). The rather large depth range results from varying wind and current conditions affecting the sets.

A composite time-depth curve of the first five sets of the hybrid purse seine is also shown in fig 6. Agreement with the predicted range for a scaled-up Model II is considered good, allowing that the hybrid purse seine is deeper than the conventional seine by one strip of body netting.

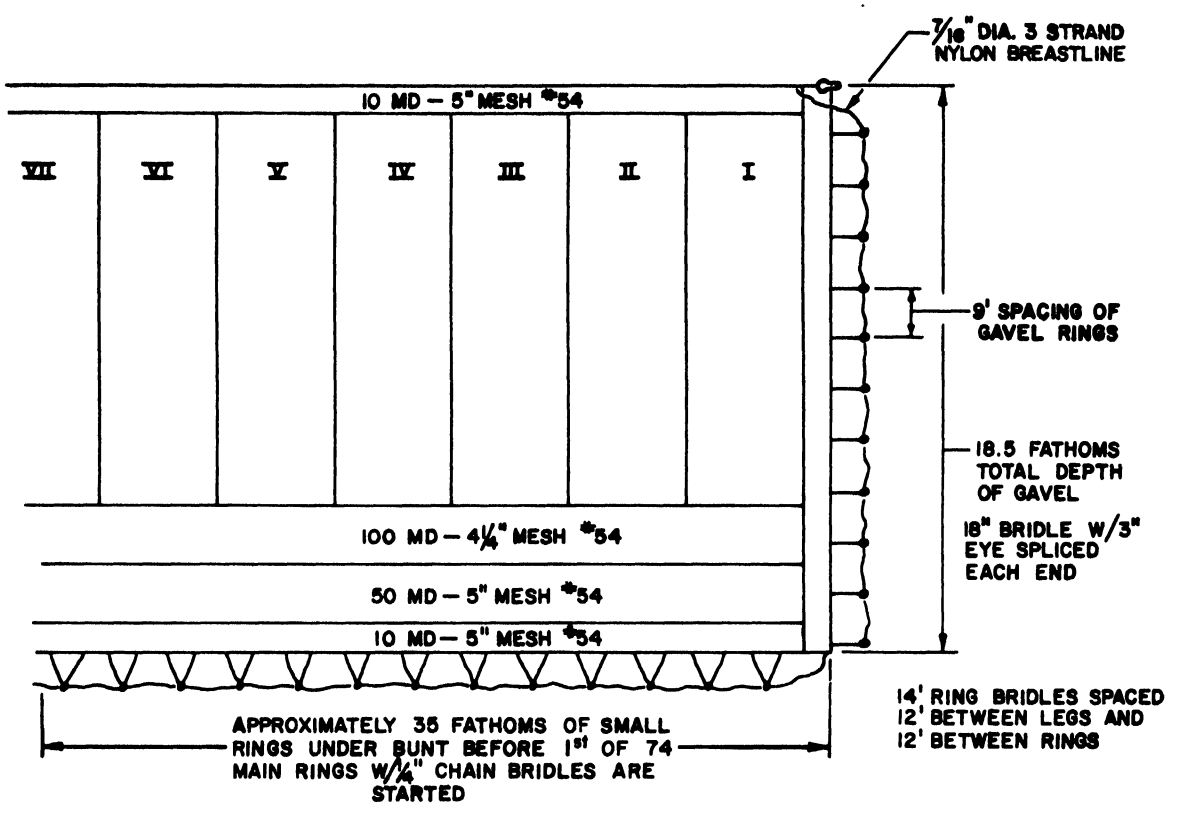

Fig 4. Hybrid tuna purse seine—gavel or breastline and purse ring spacing

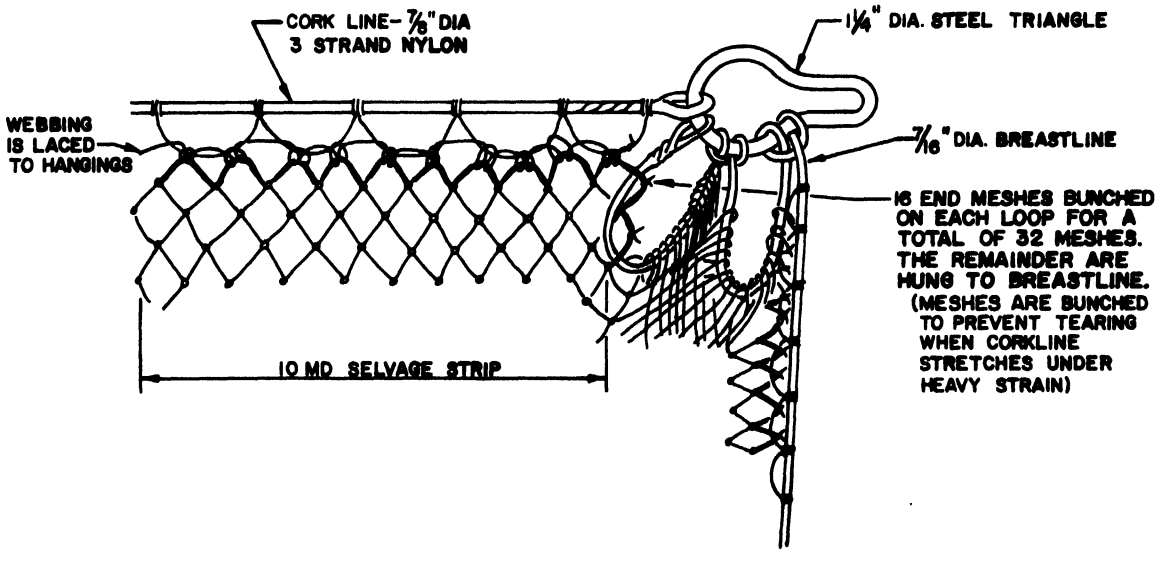

Fig 5. Hybrid tuna purse seine—bunt end detail

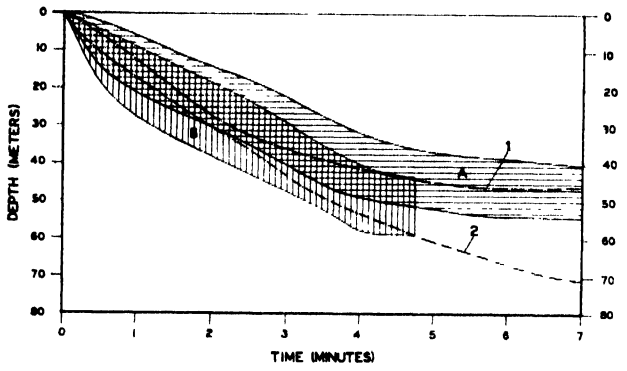

Fig 6. Predicted and actual sinking performance of hybrid purse seine. A = range of sinking performance of standard seven-strip tuna purse seine; B = predicted range of sinking performance of hybrid purse seine; 1 = mean sinking performance of standard seven-strip tuna purse seine; 2 = mean of first five sets of hybrid purse seine

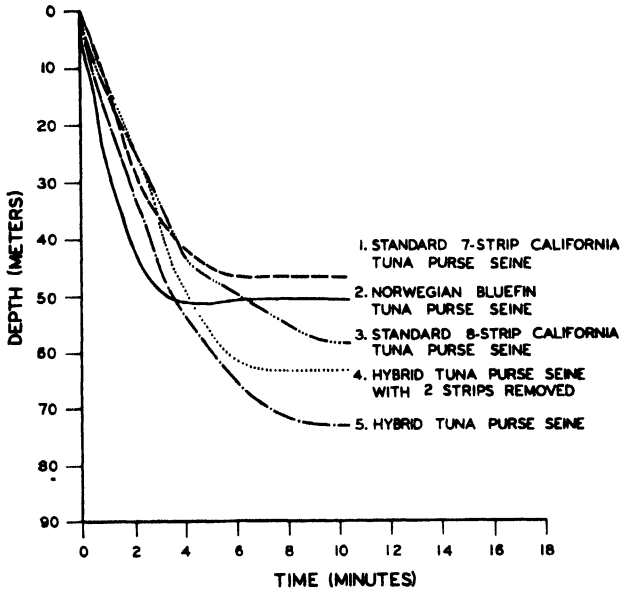

Fig 7. Midnet BKG traces from water entry to maximum depths. Source: 1—original BKG data. Means of nine sets of one net. 2—Hamre, 1963. 3—original BKG data. Means of nine sets of two nets. 4—original BKG data from one set of modified hybrid purse seine. 5—means of first five sets of hybrid purse seine

In fig 7 the sink rates and maximum depths of the Norwegian bluefin tuna purse seine and two California tuna purse seines are compared with those of the hybrid purse seine. While there is some crossing of lines, appearances indicate the initial sink rates generally are inversely related to the k_h of the nets, i.e. the two California purse seines, with $k_h = 0.91$, show the slowest sink rates, and the Norwegian purse seine, with $k_h = 0.40$, the fastest.

It is interesting to compare the hybrid purse seine modified to seven strips (see section 5) with the standard seven-strip California tuna purse seine. The former sinks approximately 9 fm (16.5 m) deeper, even though the numbers of body strips and therefore the stretched depth is the same in the two nets. The improved sinking performance results from the combination of (i) lower k_h, (ii) low ratio of corkline length to leadline length (gavels, in this respect, add to leadline length) and (iii) lighter netting.

Comparison of net ends

One objective of the hybrid purse seine design was to create a better underwater configuration at the net ends, reducing the gap under the boat, through which fish can escape and offering more efficient and economical use of netting. Figure 8 compares the wing ends of the hybrid purse seine and the standard seven-strip California purse seine at average maximum depth. In the section shown, the hybrid net is only four strips deep, whereas the standard purse seine is seven strips deep throughout its entire length. The hybrid purse seine's wing ends fish, on average, about 14 fm deeper with 1.7 times more filtering area using only about 0.62 the amount of body strip netting as the standard net. This improvement is due to three things: (i) the net ends laced to a long gavel line instead of gathering all of the webbing to a single point (the end triangle or swivel), (ii) the decreased k_h, and (iii) the setback of the first main purse rings to 35 fm (64 m) from the net end rings, allowing the gavels to hang free of the influence of the purseline.

Although pursing the gavels represents an extra task over the operation of the standard purse seine, they can be handled without loss of time. It was soon realized that only the front gavel, adjacent to the main bunt,

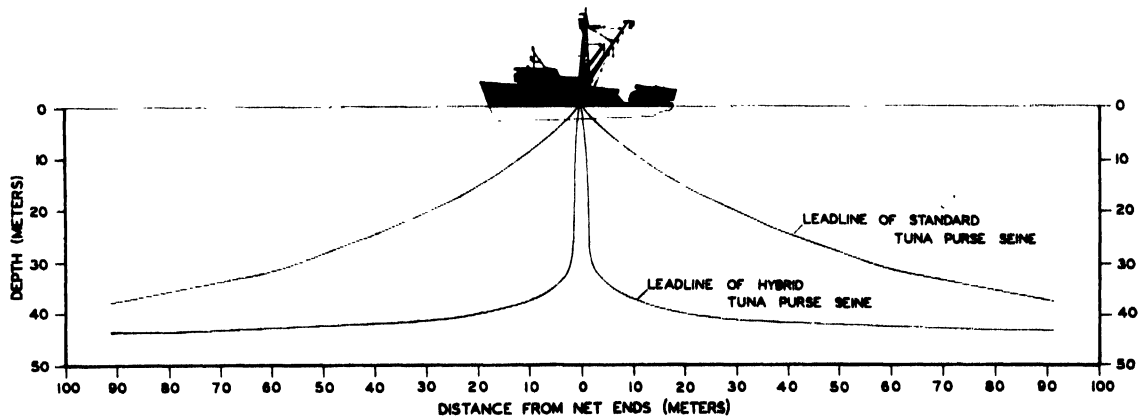

Fig 8. Net ends of hybrid purse seine and standard seven-strip tuna purse seine compared. Profiles shown are deduced from maximum depths of BKG traces. Tuna purse seiner shown to scale

needed to be pursed. There has been no tendency for the gavel to foul or roll up in the purseline.

The circle formed by the hybrid seine maintained its roundness and initial diameter well into the pursing stage. The floatline did not wrinkle up into folds, as is customary on conventional seines with 10 per cent shorter leadlines. The vessel has less tendency to pull itself into the centre with large pockets forming around the bow and stern, as happens with nearly all conventional tuna seine sets. With the hybrid seine, the roundness of the seine allows maximum holding area for the tuna that are encircled, keeping them alive longer. No measurements have been made of these phenomena, but all who have observed sets made by the hybrid purse seine agree in these subjective observations.

FISHING TESTS

The hybrid purse seine was placed on the purse seiner M/V *Liberty*, out of San Pedro, California, for fishing tests beginning August 1968. The previous rate of success of *Liberty* under its present crew (since 1 January 1968) was 56 per cent, not significantly different from that of other vessels fishing in the same area, which averaged 60 per cent. The net that *Liberty* had previously used was a standard U.S. tuna purse seine, seven strips deep by 350 fm (823 m) long with netting hung at a k_h of approximately 0.91.

During the remainder of 1968, after the close of the yellowfin season, *Liberty* made 19 sets with the new net: one on bonito, two on bluefin tuna, and 16 on albacore tuna. Seventeen sets were successful. The captain and crew were impressed with the net's sinking performance, the maintenance of the set's initial diameter well into pursing and, above all, its fish-catching ability. The only complaint was difficulty in stacking the net because of its incremental hang in. With more netting nearer the floats than the leadline, the net left the power block with a twisting motion with occasional large piles of netting falling down near the floatline. The power block had to be stopped often or slowed while the net was straightened out, and the net required 25 to 50 per cent longer than usual to stack.

During the first trip of *Liberty* in 1969, the hybrid seine was used under conditions for which it was not designed—on porpoise and in shallow waters. Because of the rough treatment received by the net when porpoise are involved, stouter than normal netting is usually used and a constant, not incremental k_h is needed for "backing down", a tactic of pulling the corkline underwater to allow porpoise to escape (Perrin, 1969).

Several sets on porpoise confirmed the belief that the hybrid purse seine, as hung, was not suitable for this type of fishing, because of a low rate of porpoise escapement and damage to the net by porpoise. After shipboard repairs were made, the seine was used around the Revillagigedo Islands off Mexico, a place well known for rough, shoaling bottoms (and often plentiful tuna). The ill-fated trip ended with half a load of fish when the net snagged bottom, and over half the leadline was lost. Seven of 13 sets were successful.

In anticipation of further porpoise fishing during the yellowfin tuna season, we temporarily modified the seine by increasing the k_h to 0.83 and removing two strips. The incremental hang-in was abandoned. We replaced 250 fm (457 m) of lost leadline in the back portion of the net with $\frac{7}{16}$ in (11.1 mm) dia chain.

During the following three trips, March to June 1969, there was no opportunity to test the net, in its modified form, on porpoise. On schoolfish—bluefin, skipjack, and yellowfin tuna, and a small amount of bonito—however, it performed well. Of 52 sets, 33 (63 per cent) were successful. Schools as large as 100 short T (91 metric T) were landed, using only the main bunt, thus proving the adequacy of the light-weight netting for handling heavy loads of fish. The sink rate and depth of the hybrid purse seine, although it had been reduced to seven strips, greatly exceeded that of the standard seven-strip purse seine (fig 7).

In June 1969, after the close of the yellowfin tuna season, the hybrid seine was restored to its original configuration with the exception of the incremental hang-in. With incremental hang-in, the mean k_h of all the strips at mid-net was 0.79. We rehung the seine at this new k_h, lacing all the strips together evenly. The leadline, with the chain replacement made in the previous modification, remained the same. We then checked the net's sinking performance with BKG's and found the curves to be nearly identical to those obtained with its original configuration.

Two more trips were made with the hybrid purse seine before *Liberty* ceased fishing for the year. During those trips, a total of 37 sets were made, of which 18 (49 per cent) were successful.

Fishing test results

We compared the rates of success of *Liberty* and other vessels for the period during which *Liberty* was operated under its present ownership and crew (since 1 January 1968). Fishermen's logbook data were made available to us for this purpose by the Inter-American Tropical Tuna Commission (IATTC). Because the rate of success may vary with time, area, vessel size, and type of fishing (e.g. species and "porpoise" fish versus schoolfish—Craig Orange, IATTC, personal communication), data were used only from those vessels most comparable to *Liberty* in these respects. This was accomplished by simply tabulating sets made north of 20°N latitude and in the Revillagigedo Islands—Hurricane Bank area. This northern area of the fishery nearly approximates the traditional fishing grounds of small- to medium-size purse seiners like *Liberty*, whose main strategy is to concentrate on yellowfin, skipjack and bluefin tunas as these fish appear seasonally. The porpoise fishery is centred in southern, more tropical waters (Perrin, 1969). Moreover, at any given time the majority of the small purse seiner fleet may usually be found concentrated in a smaller area within the northern region just defined, as they move with the fish. The few sets made on porpoise were omitted from these data, except during one quarter when *Liberty* made sets on porpoise. For two quarters when *Liberty* fished farther south, we tabulated data from other vessels fishing in the same 5° squares.

The purse seines carried by the other vessels are all versions of the standard U.S. tuna purse seine described by McNeely (1961) with only minor variations in design and size.

In order to examine our set data by time, we tabulated them by trips in the same manner as the IATTC compiles data obtained from fishermen's logbooks—by quarters of year in which the trips originated. The results in success ratio by quarters of years are shown in fig 9. *Liberty's*

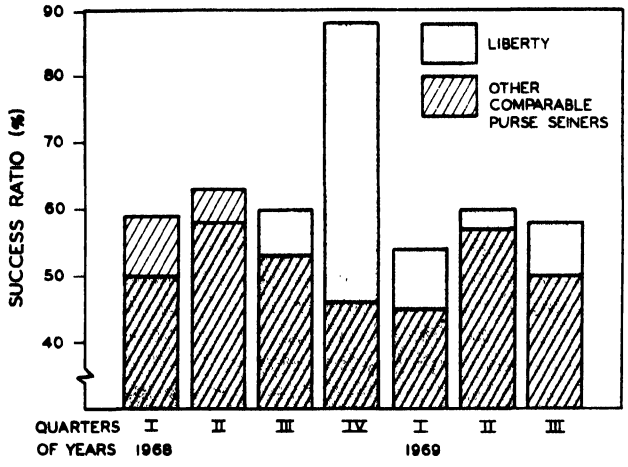

Fig 9. Success ratios of Liberty *compared to similar purse seiners by quarters of years. Hybrid purse seine added to* Liberty *during third quarter of 1968*

success ratio, which commenced below that of comparable vessels, surpassed them in the quarter in which she started using the hybrid purse seine and maintained these higher levels during the remainder of the test period.

For statistical comparisons, all of the set data are summarized in Table 2.

2. SET DATA OF *Liberty* COMPARED WITH OTHER COMPARABLE NERS BEFORE AND DURING THE USE OF THE HYBRID PURSE SEINE BY *Liberty*

	Before use of hybrid purse seine by Liberty		*During use of hybrid purse seine by* Liberty	
	Number of sets	*Per cent success*	*Number of sets*	*Per cent success*
Liberty				
Successful sets	44		75	
Unsuccessful sets	35	56	46	62
Total sets	79		121	
Other comparable purse seiners				
Successful sets	2,067		1,525	
Unsuccessful sets	1,473	58	1,416	52
Total sets	3,540		2,941	

All adjacent pairs around the perimeter of the table were tested for significant differences at the 0.05 level using chi-square in 2×2 contingency tables. The only significant difference was between other comparable purse seiners and *Liberty* during her use of the hybrid purse seine.

DISCUSSION AND CONCLUSIONS

Some shortcomings in the fishing test data hampered their accurate interpretation. Among these are the modifications of the hybrid purse seine during the test period, and the variability encountered in fishing conditions and species fished. Our testing vessel was an unpaid volunteer and had to continue normal operations without outside interference in this highly competitive fishery; therefore this phase of the experiment could not be carefully controlled.

Our interpretation of the data is that because there were no differences between the success of the *Liberty* and success of the other boats before the new net was used and because no other variable has been introduced or cause of variation detected, we may ascribe any difference after the new net was adopted as being associated with the *Liberty's* use of the hybrid purse seine.

Difficulty was also encountered in precisely interpreting the sinking data of purse seines because of lack of control over natural conditions affecting the set and because of the absence of basic studies that define relationships between net performance and setting conditions. For example, the effect of wind and current driving boat and net apart is to limit the seine's maximum depth. This relationship has often been observed but never defined quantitatively. Indeed, the presence of a current may often go undetected. It could probably be shown that pursing speed and mesh and twine sizes, among other factors, also influence the wind and current's effect on the seine's sinking. Until such basic research on purse seine performance has been conducted, it is necessary to use averages of repeated measurements.

The ability to make high speed sets is of great importance to eastern tropical Pacific tuna purse seiners which make sets at speeds of 7 to 8 kn, and sometimes faster. This leads us to believe that tuna seines should be hung at k_h of no less than 0.7, preferably between 0.75 and 0.80. Although limitation of k_h does not permit maximum depth per given strip, it does preclude tearing of netting when high speed sets are necessary. Seines can always be made deeper by adding additional strips. Besides, any deviation to one side or the other of the square meshes obtained with $k_h = 0.7$ results in decreasing economic efficiency of use of netting. With $k_h > 0.7$, square meshes will be achieved at some point during sinking or pursing of the seine; but at $k_h > 0.7$, this is never possible.

The effects of the main features of the hybrid purse seine which differentiate it from standard U.S. tuna seines may be summarized as follows:

1. Lighter netting—gives easier handling, large net size for given size of net pile, and faster sinking.

2. Lower k_h—contributes to greater sink rates and fishing depths, uses netting more economically, contributes to more open net circle for a longer time during set but may cause some difficulty for porpoise escapement.

3. Tapering—maintains depth where needed, eliminates unnecessary netting at ends, and aids in drying-up fish prior to brailing.

4. Incremental hang-in—might offer better pur-

sing configuration but contributes to handling difficulty and low porpoise escapement.

5. Floatline and leadline of equal lengths—contributes to greater sink rates and fishing depth and more open net circle longer during set.

6. Gavels with breast pursing lines—uses netting at net ends more economically, reduces escape gap under the purse seiner and adds to the effective length of the leadline.

7. Setback of main purse rings from net ends—contributes to vertical hanging of gavels beneath vessel, reducing this escape gap.

Acknowledgments

The authors deeply appreciate the cooperation of the owners, captain and crew of *Liberty* who so generously provided their ship time, space, personal cooperation, and hospitality during the testing of the hybrid purse seine.

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Icelandic Purse Seines with Double Leadline—Construction and Experience

Gudni Thorsteinsson

Sennes coulissantes islandaises a double ligne de plombs—construction et essais

L'idée d'améliorer la fermeture des seines coulissantes pendant le coulissage par l'adjonction d'une deuxième ligne de plombs située à 10 ou 15 brasses au-dessus de la ligne habituelle n'est pas nouvelle. En 1968, l'Institut de recherches marines de Reykjavik a tenté une première fois d'utiliser une senne à harengs ainsi conçue. Cette senne expérimentale diffère du modèle habituel à deux points de vues: le taux de montage de 65 à 70 pour cent est supérieur d'au moins 10 pour cent au taux habituel et la ligne de plombs (inférieure) est relativement plus courte. Les expériences controlées au bathykymographe ont montré que la deuxième ligne de plombs accroît la vitesse de fermeture; le taux de montage supérieur facilite le coulissage et le halage (réduction de la résistance de l'eau) et permet d'économiser le filet; la réduction relative de la longueur de la ligne de plombs (inférieure) facilite le lancer et réduit les risques de déchirure du filet. En outre, ce modèle s'est révélé efficace du point de vue des prises; en 1969, deux sennes coulissantes de type "capelin" de ce genre ont permis d'obtenir d'excellentes prises commerciales.

Redes islandesas de cerco con doble relinga de plomos—construcción y experiencias

La idea de mejorar el cierre de las redes de cerco empleando una segunda relinga de plomos situada 10 ó 15 brazas por encima de la ordinaria, es ya antigua. En 1968, el Instituto de Investigaciones Marítimas de Reykjavik ensayó por primera vez una red de cerco para la pesca del arenque construida de esa forma. Esta red experimental difiere de las ordinarias en dos características: el coeficiente de armadura, que va del 65 al 70 por ciento, es superior al menos en un 10 por ciento al ordinario, y la relinga de plomos (inferior) es relativamente más corta. Los experimentos, observados con batikinógrafos, han demostrado que la segunda relinga de plomos aumenta la velocidad de cierre, mientras el mayor coeficiente de armadura hace más fáciles el cerco y el halado (menor resistencia al agua) y ahorra esfuerzos a la red, y la longitud relativamente menor de la relinga de plomos (inferior) facilita el lanzamiento de la red y reduce el peligro de desgarrarla. Por otra parte, el rendimiento resultó bueno. En 1969 se obtuvieron excelentes capturas comerciales de capelán con dos redes de cerco de este tipo.

THE first attempt known to the author to use a double leadline purse seine in Iceland was made in 1930 by netmaker, Pétur Njardvík, who constructed a purse seine with a second leadline horizontally approximately 10 fm below the floatline, the maximum depth being 21 fm. The main lead weight was mounted on the upper leadline. The purpose was to prevent entanglements of the purseline (rope) and the purse ring strops on rough ground. When shooting in deeper water, the waiting time from the finish of shooting until pursing began was kept longer than usual, thus allowing the net to obtain its full sinking depth. This net was constructed for the two-dory system with the bunt in the middle.

A netmaker from Vestmannaeyjar (Westman Islands), Ingólfur Theódórsson, applied for a patent for his design of a double leadline purse seine in 1961—but so far in vain. His idea was to have the lower line without any lead but using the purse rings and the purseline as a sinking agent. The netting between the leadlines he called "bottom" and the gear a "bottom purse seine"—a name commonly used now in Iceland.

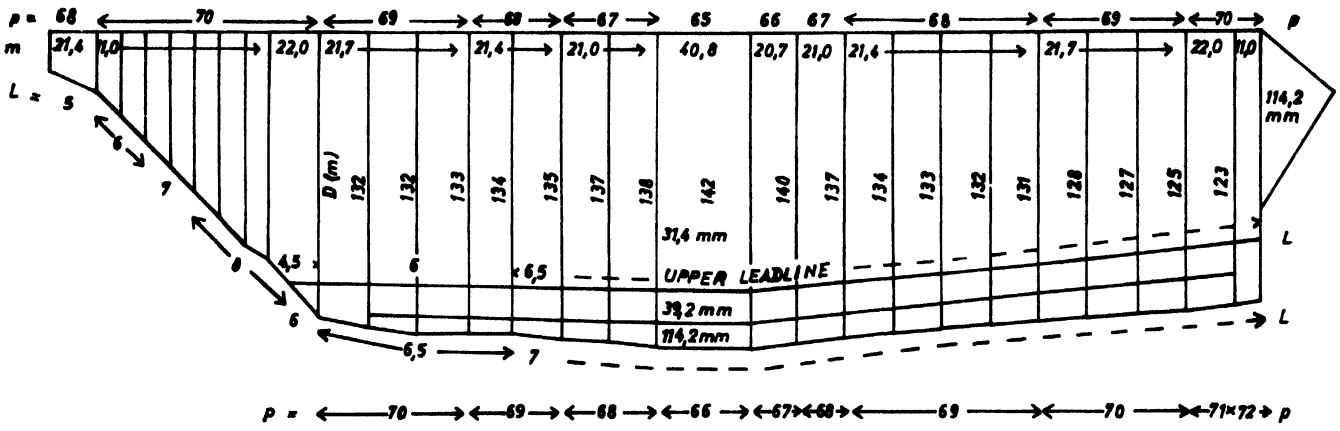

Fig 1. Double leadline herring purse seine. The symbol p *indicates the hanging ratio in per cent,* L *denotes the lead weight in kg per fm. D the actual sinking depth in metres and* m *the length in metres*

DOUBLE LEADLINE HERRING PURSE SEINE

The first experiment with a double leadline purse seine in recent years was made by the Marine Research Institute (MRI) in Reykjavík on board the chartered 245 GRT purse seiner *Soley* in June and July 1968 (Thorsteinsson, 1968 b). The main purpose was to investigate the catchability and efficiency of an experimental herring purse seine of double leadline construction. Herring search for the Icelandic fleet was the second objective.

Netmaker, Jóhann Klausen, of Eskifjördur made the original drawing of the experimental net in cooperation with the author. The gear was rigged into its final form by Nótastödin in Akranes.

The experimental purse seine differs from the usual commercial purse seines in three basic characteristics:

(a) The hanging ratio[1] is at least 10 per cent more than usual (65 to 70 per cent). In this way a given area is covered with less netting, thus decreasing the cost of the gear. Secondly, the netting meets less resistance in the water because of more open meshes. Thirdly, hauling through the power block becomes easier as the net does not form undesired bags and tangles.

(b) Length difference between the floatline and leadline (lower) is small, being only 30 cm (1 ft) on a 1000-mesh panel. This reduces danger of the net being torn during shooting (see item c).

(c) Net is equipped with two leadlines instead of one. Main purpose of this construction is to facilitate closing of purse seine during pursing operation, and getting the netting between both leadlines horizontal at an early stage of pursing, as the lower leadline is hauled upwards towards the vessel, whereas the upper leadline has the function of a hinge, holding the main netting vertical above the upper leadline.

Another advantage of dividing the total lead weight on to two leadlines is the reduced risk of tearing the net during shooting and pursing.

[1] The term "hanging ratio" means: the length of the line divided by the stretched length of the netting hung to it and multiplied by 100.

Figure 1 shows a sketch of the double leadline purse seine indicating the hanging ratio, the mesh size, the actual sinking depth of each panel of the net, the location of the leadlines and the amount of lead on each one as finally arrived at towards the end of the experiment. The length of the net panels is given only at the floatline, whereas the length at the leadline (lower) is 1 ft more for each 1000-mesh panel, as mentioned above. The length difference on the bunt is of course greater, the lower edge cut on bar. The total length of the floatline (excluding the power block choke) is 537 m (285 fm) and the length of the lower leadline is 569 m (302 fm). The length of the upper leadline is 490 m (260 fm) or about 50 m more than shown in fig 1, since the net is hung 78 per cent on that line. This is done to keep the meshes as open as possible during pursing to reduce water resistance.

For design drawing see fig 2. To avoid sharp edges on the lower side, the corners of panels 91 and 271 were cut off as indicated by broken lines in the illustration. See Table 1 for selvedge.

TABLE 1. SELVEDGE OF THE EXPERIMENTAL HERRING PURSE SEINE (FIG 2)

Panel no.		*Mesh no.*	23 *tex* ×	*Last ½ mesh*
				mm
1	top/bottom + 1 side	30	72–150	30
2	top/bottom	30	60–150	30
3–4	top/bottom	30	48–150	30
5–6	top/bottom	30	36–150	30
7–9	top/bottom	30	30–150	30
10–28	top	30	30–150	30
28	bottom + 1 side	30	30–150	30
101 + n. × 10	bottom	50	15	
112 + n. × 10	bottom	10	21–30	
A–D	top/bottom + 1 side of A	10	72–150	
9	top/bottom	200	18	
10–27	top	100	24	
10–27	top	200	18	
10–26	top	100	15	
10–26	bottom	100	15	
103 + n. × 10	bottom	10	72–150	

Sinking speed and closure

During the *Soley* cruise in June–July 1968 the purse seine was shot 35 times. The sinking depth of both lead-

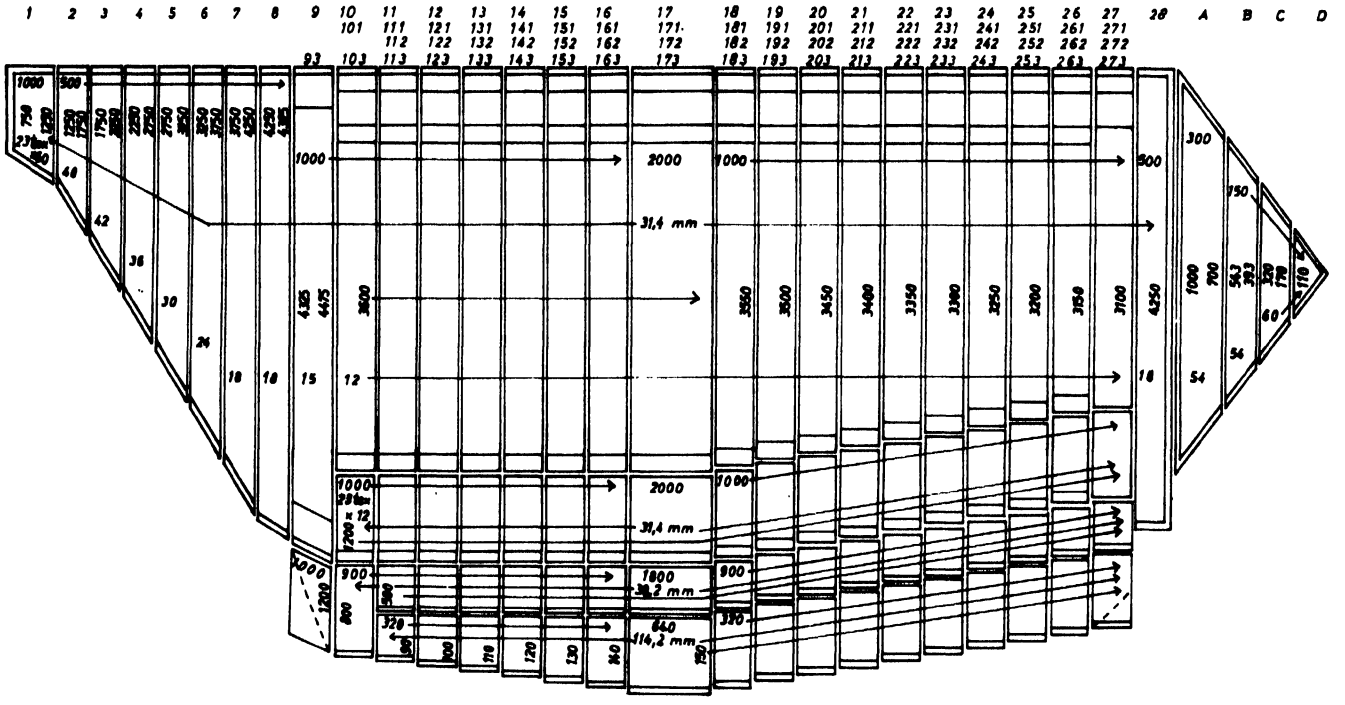

Fig 2. Double leadline herring purse seine as constructed by Mr Jóhann Klausen, Eskifjörour, in collaboration with the author. It not having been decided what size of ship would operate the net, the net pieces marked 91 + n.10 (n = 0 – 17) shown just below the main panels were ordered separately. As the experimental vessel Soley *was able to operate with the seine in its full depth, these net pieces were sewn to the main panels 9–27 on their lower edges*

lines was always measured at several places by means of bathykymographs. This equipment measures the depth (pressure) in relation to time. The aim was to compare the depth of both leadlines in relation to time in order to find out how quickly the netting between the leadlines becomes horizontal. These measurements were made by four different lead arrangements:

(a) with 4 kg/fm on the upper leadline and 9 to 10 kg/fm on the lower one;
(b) with 9 to 10 kg/fm on the lower leadline but without lead on the upper one;
(c) with 13–14 kg/fm on the lower one but without lead on the upper one, and
(d) with 7 kg/fm on the lower line and 6.5 kg/fm on the upper one (fig 1).

The lead weight on the upper lines is 12 per cent greater relative to the lower line. Thus total lead weight on this line is really 12 per cent more than indicated.

Sinking speed of lower leadline remained the same with different arrangements of the lead, if the total lead weight was constant. The average sinking depth in 5 min was 95 m (50 fm) by lead arrangement (a) and (d). Using lead arrangement (c) the sinking speed was somewhat less probably due to a strong current during that experiment. Using lead arrangement (b) (10 kg/fm) the sinking depth in 5 min was 83 m (44 fm). Since the sinking speed increases proportional to the one-half power of the lead weight, the sinking depth in 5 min should be 98 m by using 14 kg/fm, calculated from 83 m sinking depth by using 10 kg/fm. This calculated value agrees well with the measurement and shows the importance of lead weight.

It is known that the sinking speed decreases by using a higher hanging ratio and a stronger yarn number (Nédélec and Portier, 1967). Since the experimental seine was hung at least 10 per cent more than is usual in Iceland and was made from the strongest yarn used in this country, it is important to compare the sinking speed of the experimental gear with that of commercial purse seines. Sinking speed of five commercial herring purse seines was measured. Average sinking depth in 5 min out of 16 measurements proved to be 99 m. In five tests the nets were made of 23 tex × 12 yarn, in seven other tests the netting was of 23 tex × 10.5 yarn and in the remaining

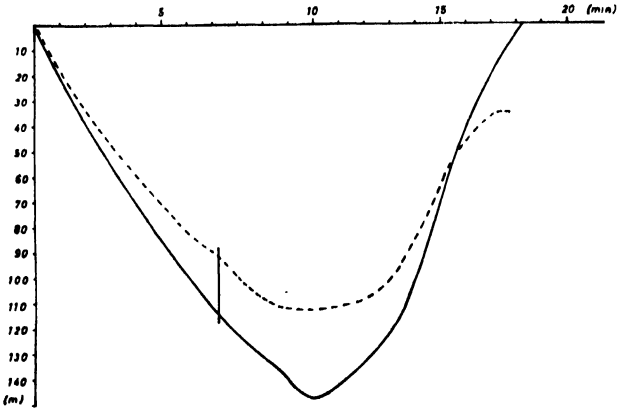

Fig 3. Sinking depth diagram of the middle part of the experimental herring net. The solid curve indicates the depth of the lower leadline as a function of time, the broken curve the depth of the upper one. Lead weight on the lower leadline is 10 kg/fm, but no lead was used on the upper one. The vertical line intersecting the curves indicates the beginning of the pursing operation

four tests the net consisted of 23 tex × 9 yarn. The lead weight was 12–15 kg/fm. The small number of observations makes it difficult to analyse the effect of each specific factor on the sinking speed. However, while comparing sinking speed in little or no current it became obvious that sinking speed increased with decreasing twine numbers. The small difference in lead weight were of minor importance (Thorsteinsson, 1968 a).

Judging from a comparison of these results with the sinking speed of the experimental purse seines, the increased hanging ratio seems to be of only small importance for sinking speed.

Sinking depth of the middle part of both leadlines relative to time is shown in figs 3 to 6. Where no lead was used on the upper lines (figs 3 and 4) the weight of the bathykymographs mounted there were equalized by using the required volume of floats. The figures clearly show that the closure of the purse seine gap takes less time by using the double leadline.

No sinking speed diagram is shown for lead arrangement (a) but in fig 7 the closure of lead arrangement (a) and (d) is compared in relation to the waiting time,

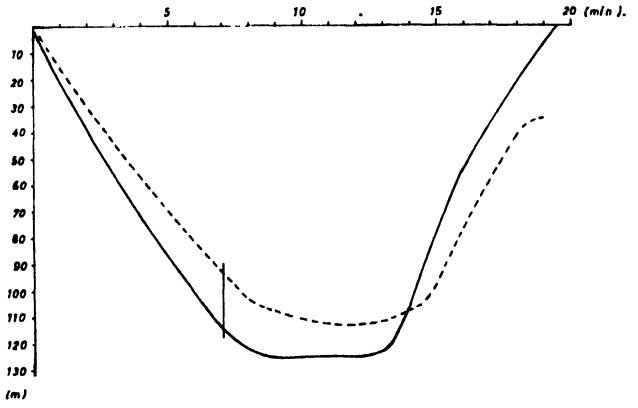

Fig 4. Sinking depth diagram of the middle panel of the experimental herring gear. Lead weights are 14 kg/fm on the lower leadline but none is used on the upper one

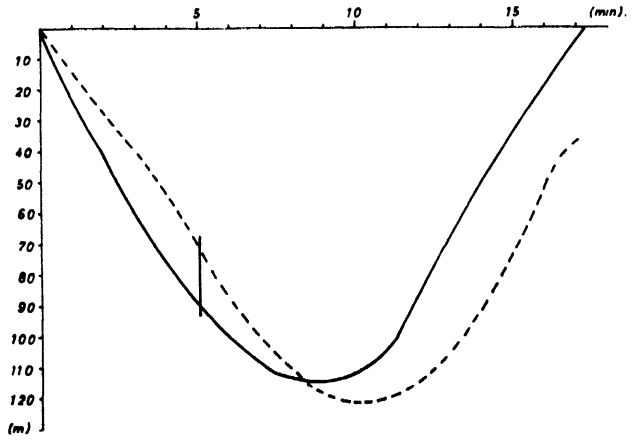

Fig 5. Sinking depth diagram of the middle panel of the experimental herring gear. Lead weights are 7 kg/fm on the lower leadline and 6.5 kg/fm on the upper one

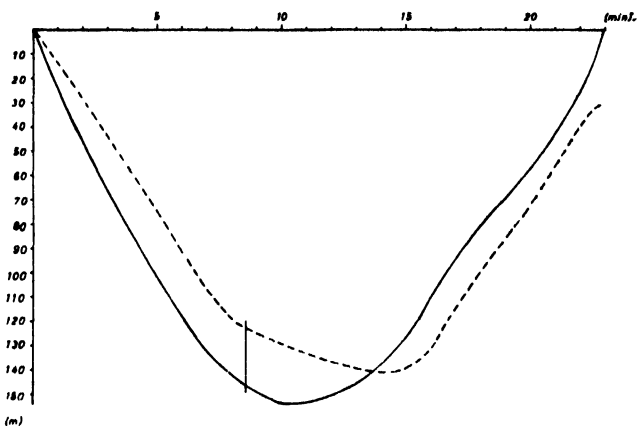

Fig 6. Sinking depth diagram of the middle panel of the experimental herring gear. Lead weights are 7 kg/fm on the lower leadline and 6.5 kg/fm on the upper one. Note the delayed beginning of pursing operation

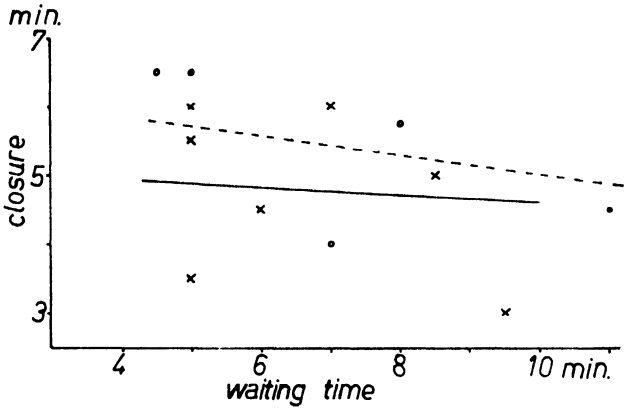

Fig 7. Closure of the middle panel of the experimental gear in relation to waiting time. The symbol X and the solid line indicate the closure by lead arrangement (d), the symbol O and the broken line are that of lead arrangement (a). Further explanations in text

i.e. from the time when the middle part of the net enters the water until pursing starts. As this diagram shows, the closure took some 40 sec longer by using lead arrangement (a). There seems to be a tendency towards a quicker closure by increasing the waiting time. Only three measurements were made without weight on the upper leadline. During these, the closure took on average 2 min and 40 sec longer than by using lead arrangement (a), and thus 3 min and 20 sec longer than using lead arrangement (d). In spite of the few observations, the quicker closure by using a double leadline construction is obvious. The closure of the net some 5 to 7 panels in either direction from the centre took somewhat less time than the closure of the middle part. These observations are not surprising considering the shape of the gear.

It is important the the netting between both leadlines gets under the school as quickly as possible to close the gap from below but not horizontally, as the school is more likely to escape under the vessel if distributed from the side. Therefore a relatively great amount of lead was always used on the lower leadline.

Experience and catch results

In June 1968 the *Soley* made seven sets on the herring grounds near the Shetland Islands where only very small schools were located. Approximately 80 metric tons were caught in five sets but two sets failed. The net was shot seven times for measurement purposes only. In July, the *Soley* was on the herring grounds off Spitzbergen. There the schools were unusually fast and hard to get. From a total of 21 sets we succeeded only seven times in surrounding a school. On those occasions when the schools were captured, a total catch of 510 metric tons resulted. The charter was over at the end of July, but the gear remained on board for commercial fishing until the end of the season, about 20 December.

In August and September only 18 sets were made, five of which failed. The remaining 13 sets yielded catches of 5 to 130 metric tons, totalling 500 tons. In this period the herring schools were moving south and southwestward and since the wind was mainly blowing from the north it was difficult for vessels like the *Soley*, without a side thruster, to make successful sets.

From the beginning of October until December, the *Soley* mainly remained on the herring grounds in the North Sea. The catch during this period was excellent, amounting to 1290 metric tons which is near peak for this time of year.

Total catch from the beginning of July thus amounted to about 2300 metric tons in 179 days or 12.8 tons per day as compared to 8.3 tons average catch per day for the whole fleet. The average vessel size was 257.5 GRT or slightly larger than the *Soley*.

It should be noted that it is easier for the crew to handle the double leadline net than the ordinary ones since the leadline (lower) is much lighter and therefore easier to lay down. The upper leadline hardly caused any extra work.

In view of the positive results already obtained in 1968, and more urgent duties, it was decided to discontinue these experiments in 1969. The gear was therefore sold and has been in use the whole season on board the purse seiner *Isleifur* from Vestmannaeyjar. Before this vessel started with the purse seine it was overhauled and the netting near the upper leadline was strengthened as it had become abraided by the lead. However, the construction was not altered.

The experience of skipper Gunnar Jónsson of *Isleifur* with the seine is similar to that already described. He is very satisfied with the quick closure and the easy hauling. Note again that the net has never been seriously torn. He was also satisfied with the catch results in the North Sea during the 1969 season. However, he points out that even the double leadline system is of no use in Icelandic waters if the schools are as wild as has been the case recently.

In spite of the positive results obtained with the experimental double leadline herring purse seine, its commercial production has not begun. Due to a negative prognosis of the herring fishery no herring purse seines were rigged in 1969 and ship owners have avoided the cost of altering their gear. There has, however, been some tendency towards increasing the hanging ratio and decreasing the length difference between float- and leadline. The experiment here described may have been responsible for this tendency.

DOUBLE LEADLINE CAPELIN PURSE SEINES

In March 1969, the first two double leadline capelin purse seines were put into use. During the 1970 season, lasting from the end of January to the beginning of April, about 15 to 20 seines of this construction will probably be used.

Reason for this quick development was the excellent catch results of such seines in 1969. Purse seiner *Gisli Arni*, which was equipped with a double leadline seine during part of the 1969 season, was top vessel, catching about 8400 metric tons or 800 tons more than the second vessel *Gigja*. While using the double leadline seine the *Gisli Arni* caught about 2400 metric tons, whereas the *Gigja* only landed about 1200 tons. The skipper of *Gisli Arni*, Eggert Gíslason, is convinced that the new gear was responsible for his success. It should also be mentioned that the vessels *Gisli Arni* and the *Gigja*, which are similar in size, used identical purse seines until the former got the new net construction. The other vessel, *Isleifur IV*, operating with double leadline gear also had good catches, although not among the top vessels of the season owing to her smaller size. The fact that the capelin schools were standing rather deep towards the end of the season favoured fishing with the relatively deep double leadline purse seines.

Construction

The first two double leadline capelin purse seines were rigged from the usual purse seines with which the vessels were operating. Both gears were altered in the way that the "bottom" (the netting between the two leadlines) was added to the depth. Thus the "bottom" was rigged to the (old) leadline which henceforth is the upper one and also to the new lower one. The purse strops and the purse rings were transferred to the new lower leadline.

The total maximum stretched depth of the gear of *Isleifur IV* was 36–5/6 fm, the bottom being 9 fm. The gear of the *Gisli Arni* was 42 fm deep, of which 7 fm were in the bottom net. The lead weight of the gear of *Isleifur IV* in the middle part was 9.4 kg/fm on the upper leadline against 2 kg/fm on the lower one compared with 9.0 kg/fm and 3 kg/fm respectively on the net of *Gisli Arni*.

The sinking depth diagrams for these two purse seines are shown in figs 8 and 9. Unfortunately, no measurements were carried out on the sinking depth of usual capelin purse seines. Both diagrams show that the lower leadline is below the upper one in every stage during sinking, reducing the risk of entanglements.

Comparing the two figures it becomes obvious that the shorter waiting time and greater pursing speed in the first stage of the pursing operation, as done on board the *Isleifur IV*, closes the gap more quickly. This method, however, permitted the lower leadline to achieve only 78.5 per cent of its actual sinking depth, whereas the upper leadline sank 93 per cent of its actual sinking depth. It is also clear that the closure occurred nearly horizontally. Due to the slower purse seining operation of the *Gisli Arni*, its two leadlines achieved about 92 per

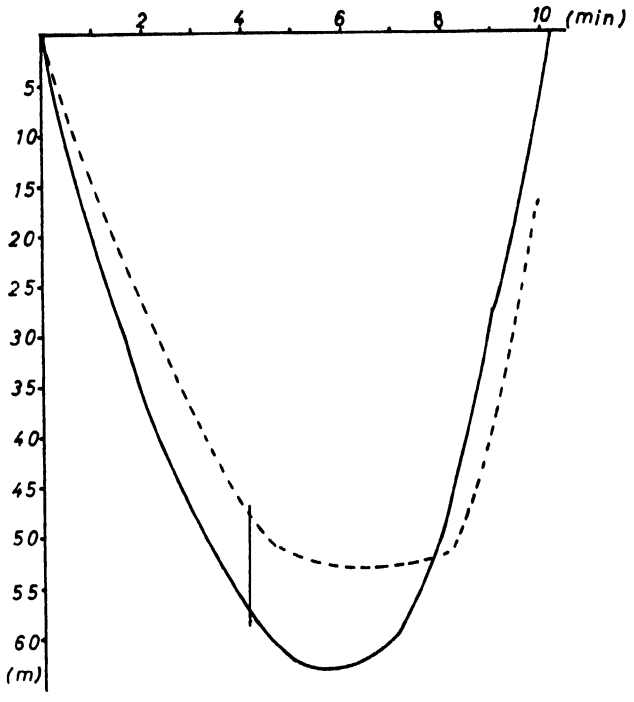

Fig 8. Sinking depth diagram of the middle panel of the double leadline capelin purse seine of m.s. Gisli Arni

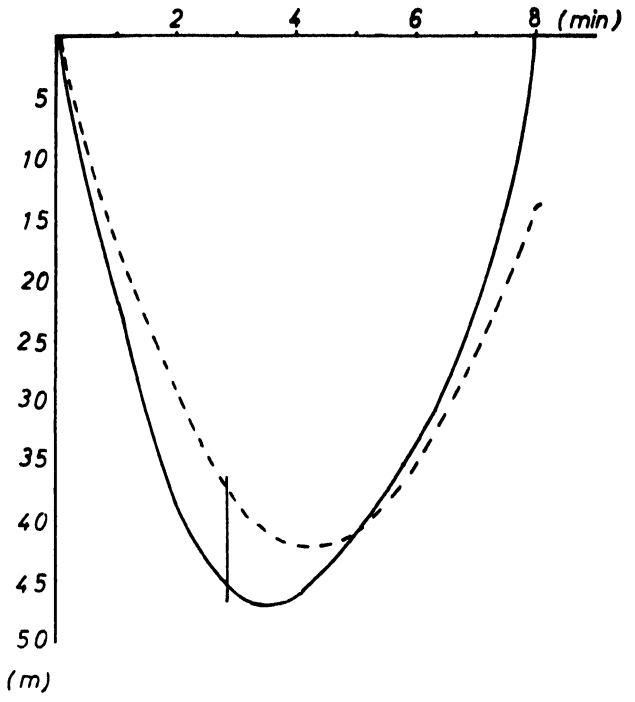

Fig 9. Sinking depth diagram of the middle panel of the double leadline capelin purse seine of m.s. Isleifur IV

cent of the actual sinking depth. The gap in this case is thus closed more from below. It must be emphasized that the schools were standing much deeper when the measurements on *Gisli Arni* were carried out.

In fig 10 an example of a "bottom" capelin purse seine is demonstrated. The expression "double leadline" net is in this case out of place, as no lead is used on the lower edge of the bottom. With this arrangement, the purse seine gap will certainly close very quickly, but the school is disturbed more from the sides. An important fact is that capelin is much easier to catch than herring. By increasing the waiting time it is also possible to get the "bottom" well below the leadline. Although not very likely, it is conceivable that the "bottom"—due to unusual shooting manoeuvres and/or strong currents—could get on the outer side of the net circle, thus causing serious trouble.

The hanging ratio of the purse seine shown in fig 10 is similar to that of usual nets. The hanging ratio of the main panels on their lower edge is the same as indicated for the upper edge of the "bottom", shown below.

The netting used in making the "bottom" is mainly taken from old herring purse seines. Therefore relatively high twine numbers are used, up to 23 tex × 21, but 23 tex × 12 is also used. A few different twine numbers might also be found in the same "bottom". The shape of

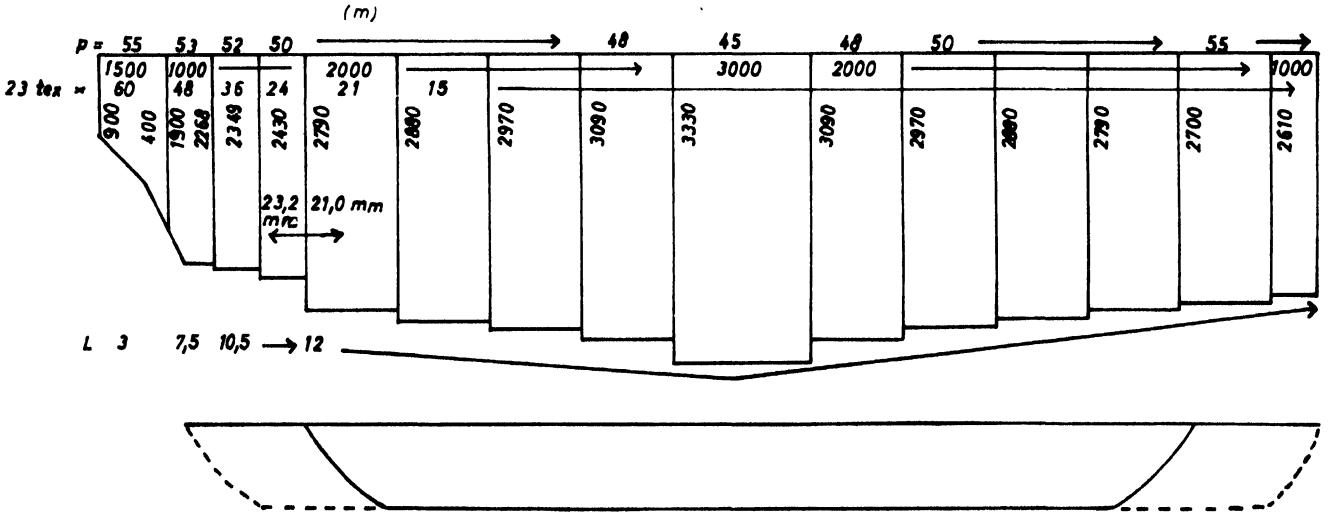

Fig 10. Design drawing of a "bottom" capelin purse seine made by Ingólfur Theódórsson, Vestmannaeyjar. The symbol p *indicates the hanging ratio in per cent and* L *the lead weight in kg per fm*

the "bottom" is shown by solid lines whereas the broken lines indicate a bottom for another seine of the same dimensions. The cutting rate at both ends is 1 mesh, 1 bar then all meshes, as the oval shape of the gear is already achieved by the main panels. Some "bottoms" are nevertheless deeper at the middle part. The purse strops are extended up to the real leadline. If it can safely be assumed that the netting of the "bottom" is strong, only every second strop is extended with the exception of the middle part where every strop is extended.

The total length of the floatline is 285 m (151 fm), the leadline being 32 m (17 fm) longer. Rigging and selvedge is as usual and is dealt with in another paper of this Conference (Thorsteinsson, 1970).

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DISCUSSION

MATERIALS, NET DESIGN AND CONSTRUCTION

Wathne (FAO) Rapporteur: Materials for use in purse seines have seen few significant changes since the last Gear Congress. At present, major purse seine fisheries in the Atlantic and eastern Pacific use nylon netting exclusively. The Japanese have taken a somewhat broader outlook on the netting material problem and made rather extensive studies. As pointed out by **Nakamura** these have resulted in seines being constructed in various materials. Generally the objective of Japanese seine design has been to achieve a heavier net for faster sinking by using netting of high density material such as vinylidene chloride, polyvinyl alcohol or polyester and even a combination twine made of nylon for strength and polyvinyl alcohol for weight. Nylon is used for smaller nets but in the larger seines other materials are used in major sections. Other recent trends in Japan mentioned by Japan Chemical Fibres Association are continuous filaments replacing staple fibre vinylon.

In addition to utilizing netting material which assists in achieving a high sinking rate, the Japanese also take advantage of the reduced water resistance of knotless netting. Both twisted and Raschel knotless netting are used in sections of the seine which take the least strain. Knotted netting is used in sections of high load such as selvedge strips and the bunt. Twisted knotless has the disadvantage of being difficult to repair and, according to **Nakamura**, this is leading to increased use of the Raschel type in Japan. Materials for mounting lines used in purse seines have also reached a degree of standardization regionally. In the eastern Pacific, normal nylon ropes are used. In Scandinavia, double lines of opposite lay of terylene are used and in Japan vinylon, polypropylene and polyethylene are used.

The problems associated with seine materials which are encountered in purse seining are well documented by **Sugano** and **Yamamura**. They describe the Japanese two-boat purse seine fishery off West Africa. The major problem encountered was the different rates of stretching and shrinking of components during operations. After 92 sets the gear was measured. The netting had shrunk 5 per cent, the floatline had stretched 5 per cent and the netline had shrunk 25 per cent. The result was a seine that had virtually ceased to fish. Although alterations were made by replacing some netting and rehanging, the original fishing performance was not achieved (seine size: 2,325 m × 345 m).

The significance of netting materials in determining the fishing performance of a seine—particularly after some period of use—is clear. What is not fully appreciated is the significance of reduced catches resulting from this factor. It is possible that this is an area where research into better use of available materials or use of new materials can result in seines with a longer effective fishing life. Comments are invited pertaining to reduced effectiveness of seines due to stretching or shrinking or poor choice of materials.

Allen (U.S.A.) Chairman: I would first like to hear from anyone who has a contribution to add in the way of information concerning materials other than nylon.

Allers (Norway): I wondered whether the stretch factor of the ¾ in diameter floatline used in American purse seines described by **Petrich** has been checked. If so, and if it was indicated that the stretch nylon is too high, then polyester undoubtedly would be a better fibre to use.

Petrich (U.S.A.): I think nylon rope is unstable and does not give a true hang of the net. I agree that less elastic ropes should be used to ensure a more stable net configuration.

Allen (U.S.A.) Chairman: Are there any comments with regard to materials that have been found useful or more useful than nylon in purse seines?

Nomura (Japan): The materials used for Japanese purse seines differ according to the type of fisheries. Necessary characteristics of materials for purse seines are: (1) **Breaking strength**—This is the most important factor for purse seine material. Elastic recovery is also very necessary to hold enough energy against impact force. (2) **Specific gravity**—This is related to the sinking speed of the purse seine. (3) **Low hydraulic resistance of net**—This is also a very important factor to avoid distortion of the net by strong currents or two different directions of the current. Considerations here are the specific gravity of twine, twine size and mesh size. The following materials are presently being used in Japanese purse seines:

Sardine seines: For two-boat seines, nylon is very popular because of its strength. Also, a combination twine of nylon and polyvinylidene chloride is frequently used to obtain a greater specific gravity than nylon alone.

Horse mackerel and mackerel seines: This is the one-boat type in the East China Sea and Japan Sea. The materials used are continuous multifilament polyvinyl alcohol and polyester. The former is a little lighter, 1.31 specific gravity and the latter 1.38.

Tuna seines: One boat and two-boat types are used in this fishery. These nets require especially strong material and use nylon for the bunt and selvedges. In the main body continuous filament polyvinyl alcohol is used for reasons of economy. Also polyester and a combination twine of polyester and polyvinyl alcohol is sometimes used.

Allen (U.S.A.) Chairman: Are there any contributions with regard to the change in the fishing efficiency of purse seines during the life of the seine?

Hellevang (FAO): We have checked about 100 different purse seines in Peru. Ninety per cent have a nylon floatline and a chain leadline. This combination results in a stretching of the floatline of 10–15 per cent after 40–50 sets and it is then necessary to rehang the net. If the nets were hung on terylene rope (minimum 1 in diameter) the stretching would be reduced to 4 to 5 per cent.

Ben-Yami (Israel): In sardine purse seine netting we were using terylene with excellent results. The price of this material was 25 per cent higher than nylon. In addition the terylene is, area per area, 20 per cent heavier than equal strength nylon. The price difference was such that fishermen have now switched completely to nylon.

Petrich (U.S.A.): American fishermen have tried various additives such as stainless steel and copper to protect the net from sharks but none of these experiments have been successful.

Wathne (FAO) Rapporteur: The next subject, net design in relation to fish behaviour, is dealt with in only three papers, two of which, by **Thorsteinsson** and by **Green, Jurkovich** and **Petrich,** relate to net designs still under development. The third, by **Iitaka,** describes seine designs in commercial use in Japan. All seine designs are based fundamentally on the behaviour of the fish which they are intended to take and therefore comments regarding design characteristics of commercial seines are welcomed.

Iitaka, in describing purse seine design in Japan, points out that the success of the seining operation depends largely on the speed of setting and pursing which are in turn dependent on the sinking speed of the net. To achieve rapid sinking Japanese designers utilize netting material of higher density than nylon, increase the use of knotless netting and increase the weight used on the leadline. Netting material of greater density which has been introduced includes polyester and mixtures of polyamide and polyvinylidene chloride (saran). Although these materials sacrifice strength somewhat, it is felt that the gain in performance of the seine justifies the compromise. Both twisted and Raschel knotless netting are used widely because of their reduced resistance in the water and knotless also has a price advantage in the smaller mesh sizes. The use of weight on the leadline to speed sinking has increased in recent years but, at 1 to 2.5 kg per metre, is still far below that used on Scandinavian seines.

Thorsteinsson reports on an experimental Icelandic seine which was designed to achieve faster and fuller pursing as well as improved handling. The design differs from the conventional Scandinavian seine in three basic characteristics:

1. It has two leadlines, one far above the other. The objective is to achieve faster closing by getting the netting between the two leadlines horizontal early in the pursing operation. The upper leadline serves as a hinge which holds the upper netting more or less vertical while allowing the lower to be pulled quickly into an approximately horizontal position.
2. The hang-in ratio is much lower than normally used in Scandinavian seines—30 to 35 per cent as opposed to the usual 40 to 45 per cent. This reduces cost since less netting is required, reduces water resistance and facilitates handling—particularly in the power block.
3. The difference in floatline and leadline strength is small which reduces the possibility of damage while setting.

Results with this design in the North Atlantic have been encouraging both as regards fishing capability and handling. The poor prognosis for the herring fishery in the next years has, however, resulted in a reluctance of vessel owners to incur the costs necessary for the modification of existing seines.

Green, Jurkovich and **Petrich** describe the hybrid tuna purse seines developed by the U.S. Bureau of Commercial Fisheries. This project arose from the observation that a very high percentage of sets in the American tuna purse seine fishery were unsuccessful. The initial work was done by **Ben-Yami** and **Green** using 1:25 scale models and results of this served as the basis for the design of the full scale seine described in this paper. The major modifications to the standard commercial seine are: thinner netting, greater hang-in, tapered wing ends, incremental hanging with bottom strips successively shortened, floatline and leadline of equal length, gavels at the net ends and a marked set-back of main purse rings at each end. This design resulted in a seine which sinks faster due to the greater hang-in and the thinner netting, fishes deeper due to the greater hang-in and gives a better overall configuration in the water due to all design modifications.

Extensive tests were made with the full scale seine and results indicate that the rate of successful sets was increased by 10 per cent. In early tests the incremental hang-in of strips resulted in problems in the power block when hauling and also when assisting porpoise to escape from the seine. Subsequently, the incremental hang-in feature was abandoned.

The similarities of the Icelandic and U.S.A. experimental designs are of interest and lead to speculation of a seine incorporating additional major features of both.

Ben-Yami (Israel): I refer to the paper "Designing an Improved California Tuna Purse Seine" by **Green** and myself which was published in the *Fishery Industrial Research*, 4(5):183–207. We described a model study which led to the construction of the full-scale hybrid purse seine, which **Green** and **Petrich** will discuss later. I will discuss now two points of that study: (1) the method of using large models for designing and modifying fishing gear and (2) some rules which govern the performance of purse seines.

It is, in most cases, very difficult to follow exactly the modelling rules set by physical laws because of a lack of the necessary fine materials. With fairly large models, however, while keeping as close as possible to the theoretical rules, a rule of thumb may be quite successfully applied, but only for comparative tests. Thus, when models scaled down in a uniform manner are compared, the differences in their performance will approximately parallel the differences in the full-scale gear. We scaled down the common California tuna purse seine, studied the performance of this model, modified it, obtained performance and, finally, predicted the performance of an upscaled version of the improved model. The tests described by **Green** *et al.* have proved that our predictions were accurate. The technique of using large models for comparative evaluation of fishing gear seems to be the simplest and most convenient way for rational design and re-designing of nets and ought to be recommended.

While testing the purse seine models we observed some rules governing their performance, checked our results against those appearing in the literature which is, unfortunately, rather scarce as far as purse seine studies are concerned, and made certain deductions.

I shall begin from the known fundamentals in order to create a common starting point. Taking two strips of netting, one hung at a coefficient of 0.9, the other at 0.5, the same theoretical depth is obtained with approximately 8 meshes in the first case and 2½ meshes in the other. Now, for a tightly hung purse seine to achieve a working depth exceeding its theoretical depth, the corkline must pucker. This puckering results in a motion of the whole netting wall towards the centre of the encircled area and therefore a horizontal drag force which hampers the puckering and, consequently, interferes with the sinking of the leadline. Therefore, results

of sinking speed tests carried out using only sections of nets set in a straight line cannot be applied to purse seines. Obviously, any reduction in the horizontal drag will result in improved sinking speed. Thus, knotless and as thin as feasible netting is recommended for fast sinking purse seines.

Iitaka states that the sinking speed is proportional to the square root of the apparent leadline weight. I think this is true only within the range of rather low weighting (0.5 to 1.4 kg/m). Where the rate of weight per net area increases the less it affects the sinking speed. The effect of the floatline/leadline ratio is also of considerable importance. When this ratio is greater than one (floatline longer than leadline) the leadline must descend in an oblique direction causing a simultaneous motion of the corkline towards the centre of the circle. When the leadline is longer, it can descend vertically. Thus, for fast sinking purse seines, the corkline and the leadline lengths should be designed so that the seine, before pursing, may assume a section of a cylinder rather than of a cone or a bowl.

The results of the large model studies have demonstrated the feasibility of this method which has not been employed as often as it undoubtedly deserves.

Green (U.S.A.): The techniques of working with and basing predictions on scale models of purse seines proved to be a very useful outcome of the experiments leading to the development of the hybrid purse seine. The economy of working in this way and the validity of the predictions made were quite impressive. We hope to see the use of scale models extended to more basic research on the effect of various design parameters on purse seine performance.

Freedman (U.S.S.R.): The Soviet Union has done model tests of purse seines during the last years and good practical results have been obtained.

Petrich (U.S.A.): The American tuna fishermen have not yet accepted the new hybrid purse seine. However, they certainly talk about it. The trend in recent years is certainly to obtain faster sinking nets and fishermen are adding strips of finer material to the nets to bring this about; however, not always over the entire length of the net. They are also adding netting and increasing the hanging rate. This not because of the new hybrid purse seine but has been the trend for some time.

Thorsteinsson (Iceland): The experimental Icelandic net has a 10 per cent less hanging-in ratio than commercial seines and less difference in length of floatline and leadline—the leadline being hung-in only 1 per cent less than the floatline. It was hoped that during the 1970 season experience could be gathered with this net, but since the capelin was very close to the coast in shallow waters the net was unsuitable.

Alverson (U.S.A.): Performance can be measured in a number of ways other than rate of successful sets and a fuller evaluation of performance of the hybrid net must be made before its value in fisheries can be established.

Green (U.S.A.): I agree with **Alverson** that the rate of success is not the only measure of performance of new gear. It is clear that rate of successful sets is of most importance in a fishery where every set has to produce fish; that is, when schools are scarce, while this may not be so in a fishery where it is necessary to make many sets during one day. The principal features of the hybrid seine are being enlarged upon to produce an experimental net for skipjack fishing in tropical waters.

Hamre (Norway): In the Norwegian purse seines the hanging coefficient (defined as length of line to stretched netting) varies from 0.4 to 0.6. With such a great hang-in, the netting put into the gear cannot be properly utilized due to the considerable loss in filtering area when the net is pursed. This can be shown mathematically, and in 1965 the Institute of Marine Research suggested building a net in which all the netting hung with square meshes when partly pursed. It was not possible at that time to obtain the necessary financial support for this, and the project remained pending until last year, when a skipper said he wanted to try the new net design. He was prepared to carry the expense himself, but has since received some financial support from government sources.

The principle of this design is to hang the net in such a way that maximum volume is obtained out of a given amount of netting, pre-supposing a certain shape when pursed. In the present case it was agreed to use the same amount of netting as existed in the herring net the skipper was using at the time. This net is 332 fathoms long and 98 fathoms deep. The new net has the same length of line but was some 40 fathoms deeper. The weight on the leadline was increased from 4,000 to 5,000 kg. The net has not yet been put into operation but some test sets have been carried out. The preliminary results are rather promising and indicate that it may be able to catch fish schools located some 30 fathoms below the catching range of the old net.

Allers (Norway): I will comment on the construction pattern in the Iceland/Norwegian purse seines.

It is about time that a hard look be taken at some of the common practices for I believe that these seines are much too complex in netting design. To illustrate this I refer to **Thorsteinsson's** paper where in Table III he describes the composition of twine sizes in a graded selvedge. Personally, I feel this is a waste of technical effort from a netting machine.

Apart from this little detail it is also necessary to introduce in the body of the seine horizontal netting strips taken directly from the machines, thus reducing the cost of netting by at least 5 per cent. With the vertical strips presently used there is a serious lack of versatility for combination fishing in deep and shallow water. With horizontal netting strips you may change the nets in depth very quickly. Further, there is no doubt that a purse seine with horizontal strips can be repaired much easier and quicker. In Eastern Canada I have observed seines badly damaged along the leadline, being fit for fishing again after one day's repair. If this had been an Icelandic/Norwegian seine with vertical strips it would have taken at least three days to get the net fishing again. Also with horizontal strips it is far easier to include in this net construction what I term as tearing strips for shallow water fishing. This strip of heavy netting (about 25 meshes deep) may be located 400 to 800 meshes above the leadline and will prevent tearing further into the net, whereas an Icelandic/Norwegian purse seine would be put completely out of action under the same adverse conditions in shallow water. I still maintain, however, that the Icelandic/Norwegian seine is one of the best designed purse seines in operation in fishing today, incorporating such a feature as the tapered bunt which facilitates drying up a large catch almost entirely by the use of a deck mounted power block. But, as contended initially, the netting construction details of seines seems to be at the Ford model-T stage.

Petrich (U.S.A.): On the hybrid seine recently constructed in California we have made provision to add an apron in order to increase the depth of the net very quickly. This apron, we believe, can be attached to the net within two hours and the fishing depth increased by approximately 14 fathoms. The mesh size is larger than normal with the idea of gilling fish to determine the success of the apron. I feel that the Icelandic nets, or any other type could very easily use pucker lines for varying the depth of the seine quickly.

Nomura (Japan): I would like to make a short comment relating to sinking speeds of purse seines and also to some of the problems found in this regard with Japanese nets.

In August 1967 a 1,500 m seine was observed by using 5 depth meters fixed at equal intervals on the leadline. The sea condition was calm and current speed about 1.0 to 1.5 knots. It was found that every part of the leadline except the ends sank at an average velocity of 25 cm per second, but after pursing began it gradually slowed. Twenty minutes after setting, the net reached a depth of 110 m or 70 per cent of the stretched depth. The total weight of lead on the net was 3 tons. The centre part of the leadline sank fastest. The sinking speeds of the centre of the leadline and elapsed time after setting were:

Elapsed time after setting (min)	*Sinking speed* (cm/sec)
2	27
4	22
6	18
10	16
14	14

It is, of course, very important to have a high sinking speed. On the other hand the total weight of lead is directly related to the size of the net. According to our experiments using 1:10 models the relation between the weight of lead and the sinking speed are as follows (1 = standard net):

Weight	*Sinking speed*
2.8	1.52
1.8	1.35
0.66	0.75
0.25	0.57

Therefore, it goes without saying, that there are serious difficulties involved in increasing the sinking speed of large Japanese tuna purse seines by increasing the weight of lead.

Hamlin (U.S.A.): I have made an "instant plot" of **Nomura's** remarks on sinking rate in relation to lead weight. This showed that with no lead at all the rate of sinking reduced only by about half and suggests the importance of the density of the net materials on the sinking rate.

Hamre (Norway): Referring to **Ben-Yami's** contribution on sinking speed, he mentioned a paper presented by **Nédélec** and **Portier** (1967), which showed that sinking speed was increased when the hang-in was increased. He felt, however, that this was not a general rule and that it was more reasonable to presume that maximum sinking speed would be obtained with 0.7 hang-in because square meshes give minimum amount of netting above each fathom of leadline.

Kristjonsson (FAO): There is one feature of the Scandinavian net, the tapered bunt, which I feel is worthy of consideration for use in many other seines around the world. As you know, most purse seines still have a deep bunt all the way out to the end. This means that when pursing and hauling are completed there is still a large section of fairly useless netting under the bunt which must be taken in. In the old days this was done by hand but it is now generally strapped in with power. This takes precious time while the fish is likely to die or sink. The Scandinavians have been using tapered bunts for several years and I don't think they would like to go back to the square bunt nets. There may be cases where it is difficult to apply the technique of drying up the fish simply with the power block or any other net hauling device, but I think it can be done practically everywhere if you have a strong enough net and hauler. Difficulties in applying this technique, for instance in Peru, where the fish are very heavy and in big quantities, may be caused by using a power block not designed to cope with such a big pull. I am ready to admit that there may be cases where the tapered bunt does not apply, but I am sure it can be used in most instances.

Nilsen-Nygaard (Norway): It should be emphasized that the advocates of the tapered bunt should recognize that it is a different matter when having a big catch of say 600–700 tons in a net of only 35–45 fathoms depth than when having the same catch in a big herring net of 85 fathoms depth. One must therefore conclude that the method of Norwegians and Icelanders cannot be adapted directly in Peru and Chile because conditions are so different.

Hellevang (FAO): I agree with using the tapered bunt in the North Atlantic seine fisheries but in the Peruvian anchovy fisheries this is impossible. The seines in Peru are constructed with two or three bunts so that large catches can be separated for ease of handling. The one or two bunts not at the end of the net cannot be tapered. However, the end bunt can and it can be dried with a deck mounted power block.

Frimannsson (Iceland): What is really important is not the sinking time alone but sinking time plus pursing time (closing time). The net behaviour is obviously very dependent on winch behaviour and vessel characteristics. I would like to raise the question whether anybody has actually measured the forces, especially the dynamic forces, on the purse wire while setting and pursing in relation to time and in relation to vessel movement. I agree in principle with **Ben-Yami** who thought that there would be upper limits in applying lead. In Iceland we are now using up to 16–17 kg per fathom of lead and this is leading to problems in pursing and retrieving the net.

Hamre (Norway): **Iitaka** contains the answer to **Frimannsson's** question.

Petrich (U.S.A.): With reference to tapered bunts and the need for powerful power blocks, he agreed with **Kristjonsson** but felt that there was a lot of trial and error required before the introduction of tapered bunt nets would be possible in nearly all purse seine fisheries. He remarked as a matter of interest that old tuna purse seines were very similarly cut and that even now tuna nets were approaching the tapered bunt construction to a small degree.

Ben-Yami (Israel): We haven't measured any forces, but during our model test we were trying different types of sets—tight, fast and slow. We were pursing from a little rowing boat and then pursing from the side of a large swimming pool and we observed very large differences in the performance of the seine during pursing.

Frimannsson (Iceland): We have not yet measured these forces but we intend to do so. We have only seen the results—the broken purse wires, lost seines and even broken winches.

Allen (Chairman): As far as measuring strains, it appears that a lot of the strain is due to the vessel as well as the net because of sea conditions. In general, in applying winch gear and nets which are of the same size to two different sized vessels when one vessel may be 50 per cent greater in tonnage than the other, you find that the winch gear simply has to be stronger on the bigger vessel. It appears that it is not only directly related to the size of the net and the weight on the leadline, but the vessel size is also a consideration in determining what these strains are.

Deck Equipment for Purse Seining

H. R. Bárdarson

Equipement de pont pour la pêche à la seine coulissante

Quand la pêche à la seine coulissante à l'aide du power block a débuté en Islande en 1957, les treuils de coulissage étaient du type treuil de chalutier à deux tambours. Avec l'accroissement des dimensions des navires et des seines, on a procédé à la mise au point de treuils de coulisse spéciaux à plus grande capacité en câble et à force de traction accrue. On a ajouté également un troisième tambour pour le salabardage. Tout l'équipement nouveau est entraîné hydrauliquement; soit avec la basse pression (30 kg/cm²), soit avec la haute pression (120 à 140 kg/cm²). Conception nouvelle, le treuil de coulisse submersible est suspendu par-dessu bord jusqu'au fond de la seine où le coulissage est effectué à la plus grande profondeur possible. Jusqu'ici, il n'a seulement été essayé que par une profondeur de 50 brasses. Des mises au point complémentaires du relevage du filet comprennent la suspension du power block par une grue hydraulique permettant le pivotement, le levage et l'inclinaison de la poulie. On a introduit aussi d'autres releveurs de filets qui sont installés sur le coin tribord avant du pont du bateau. Ces releveurs utilisent deux ou trois rouleaux dont la forme est parfois cylindrique au lieu d'être en V. Il y a un intérêt croissant pour l'emploi des pompes à poissons au lieu du salabardage de la capture. Des pompes capables de déplacer 300 t/h ont été installées, parmi celles-ci le type submersible, entraîné hydrauliquement. La pompe à dépression qui nécessite peu on pas d'eau est utilisée pour pomper le poisson des cales du seineur à des navires transporteurs ou à terre.

Equipo de cubierta para la pesca con redes de cerco

En 1957, cuando los cerqueros islandeses comenzaron a emplear la polea automotriz, las maquinillas de la red de cerco eran de dos carreteles. Al aumentar las dimensiones de los barcos y de las redes, se instalaron maquinillas especiales de más capacidad de cable y fuerza de tracción, montándose también un tercer carretel para el salabardeo. Todo el nuevo equipo es hidráulico, parte de baja presión (30 kg/cm²) y parte de alta (120–140 kg/cm²). Una idea nueva es la maquinilla sumergible que se suspende del costado del barco y llega hasta la parte más baja de la red, en la que se practica el cierre de la red a la mayor profundidad posible. Hasta la fecha sólo se has ensayado en profundidades de 50 brazas. Entre otros perfeccionamientos para el halado de la red está la suspensión de la polea automotriz de una pluma hidráulica que la puede hacer girar, elevarse e inclinarse. Se han ideado también otros haladores que se instalan en el ángulo delantero de babor de la cubierta de botes; emplean dos o tres rodillos, en ocasiones de forma cilíndrica más bien que en forma de V. Aumenta el interés en el empleo de las bombas de succión para los peces en vez de salabardearlos. Se han instalado bombas capaces de elevar 300 toneladas de pescado por hora, comprendido el tipo sumergible accionado hidráulicamente. Para trasladar el pescado desde la bodega del pesquero hasta el barco transportador o a tierra, se emplea una bomba de vacío que necesita muy poca o ninguna agua.

THIS paper is mainly concerned with deck equipment for Icelandic type purse seining (fig 1), the development of which was described by J. Jakobsson (1964), and brought up to date by for instance G. Thorsteinsson at this conference.

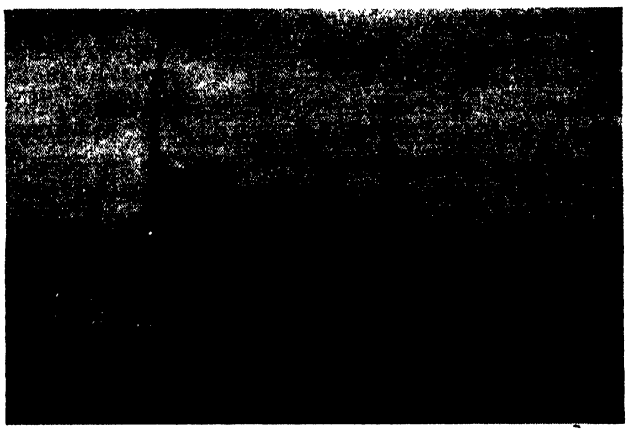


Fig 1. Icelandic purse seiner Bjarmi II, *hauling the net with power block and transport-roller*

PURSING WINCHES

Jakobsson (1964), described in detail the methods of shooting, pursing, hauling and brailing on an Icelandic herring fishing vessel.

To the end-buoy there are two lines connected. One is a rope that is a continuation of the upper edge of the net, the other is the purseline, shackled to a large float, to take the main weight of the heavy purseline off the buoy. When shooting has been completed, the buoy is retrieved by the crew. The purseline leads through the gallow blocks forward and towards the pursing winch. In the beginning of power block purse seining on Icelandic vessels, the pursing winch was exactly the same two-drum type of winch as used for trawling. It was then always placed thwartships, either just abaft of the foremast, or in front of the wheelhouse, the purseline being led to the drums through bollards on deck as needed. Most of these two-drum winches were either hydraulically or electrically driven.

When the demand for deeper and bigger purse seines developed, along with a demand for bigger vessels having more carrying capacity, and able to take greater weight of purse seines on the boat deck, the request for more powerful pursing winches followed. These bigger winches were first installed in the usual way, just abaft the main mast, at the forward end of the main deck. Later, special types and sizes of pursing winches were developed and at the same time they were placed longitudinally at the port side forward on the main deck (fig 2). In this way the guiding rollers or bollards for the purse-line were reduced to a minimum, thus reducing wear and tear on the steel-wire-rope and also the power loss in bends on the rope.

Together with the constant need for increased pulling power from the pursing winch, the size of the wire purseline increased. Therefore there was a need for a great increase in the size of the winch drums. To a certain extent this could be achieved by increasing the diameter of the sides of the drums, without increasing the centre-part diameter, but this was not satisfactory as more power was then needed for a filled drum.

When the drum is turning at constant speed, the pulling power in the wire is high on an empty drum, but speed is low due to the small diameter of the drum. When, on

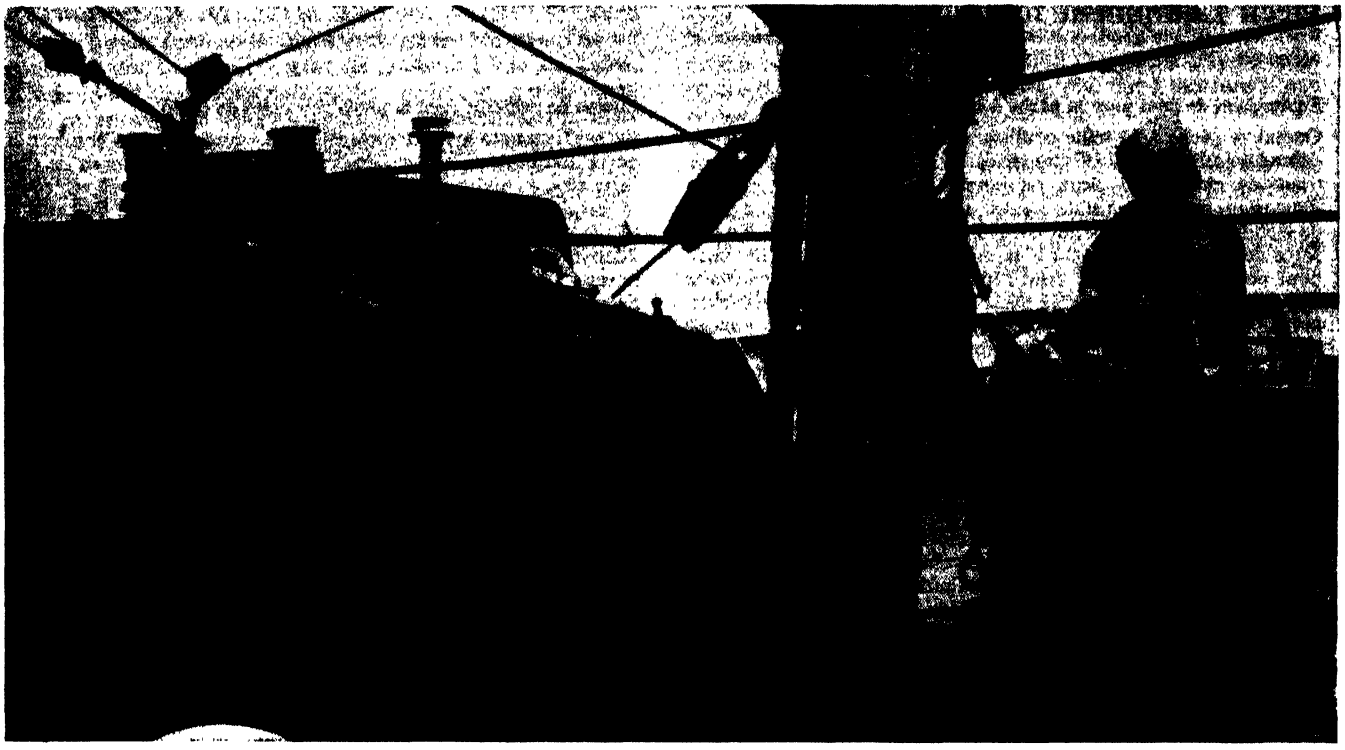


Fig 2. Modern pursing winch placed longitudinally on deck of an Icelandic purse seiner

the other hand the drum is almost filled, the pulling power is small, but the speed has increased. To illustrate this fact: a purse-seine winch with 15.8 ton f pulling power at 24 m/min pulling speed on an empty drum will have only 4.7 ton f pulling power with 17 layers of 2½ in wire on the drum, but the speed will have increased to 81 m/min.

The ideal situation would be exactly the opposite, for the pursing operation, i.e. high speed, and small pulling power at the beginning of the operation, and low speed with great pulling power at the end.

This ideal solution is difficult to achieve, but increasing the length of the drums, placing drums partly abaft and partly above each other, and positioning the winch longitudinally at port side forward on the main deck was advantageous in this respect. On the other hand this new arrangement required a separate anchor-winch to be fitted, as it is rather difficult to provide arrangements for lifting anchor-chains with the purse-winch in a longitudinal position.

Both the thwartships and longitudinally placed pursing winches have been fitted with a small separate drum for the derrick wire, for use when brailing. On the winch type where the main drums are in line, the separate wire drum is usually placed between the others, but where the main drums are placed partly abaft each other, the separate wire drum is mostly placed at one end of the winch.

Driving of the pursing winches

In former days the pursing winches, same as the trawl winches, had direct mechanical drive, either by shafting, chain drive or V-belt drive. These types of drives are now completely out of use on Icelandic fishing vessels. In vessels which had been fitted as trawlers before and converted into purse seiners, electrically driven trawl winches have been used effectively. All new vessels built for purse seining are fitted with hydraulically driven deck-machinery, either of low pressure or of "high" pressure. In this relation the term low pressure system is often used for systems operating at about 30 kg/cm², and "high" pressure for 120 to 140 kg/cm², which actually is medium pressure.

There are of course different opinions among both producers and users regarding the features of each type of hydraulic system. Those in favour of the low pressure system point out simple and rugged construction, noiseless, smooth and flexible operation, negligible wear and tear, high dependability and minimum of maintenance. Those in favour of higher pressure systems point out that it makes remote control of each machine from a central control desk easy, that the system is very flexible, and new equipment can be connected at any time. Compared with other methods of power transmission, the various components are more compact, which saves space, both on deck and in the engineroom. This simplifies installation as well as maintenance, power loss is small, and the system allows quick manoeuvrability. Compared with the development of high pressure hydraulics in other industries, it is believed to be the right system for modern fishing operation in the years to come.

Submersible pursing winch

A basically new idea is the hydraulically driven submersible pursing winch.

Hydraulic oil is supplied to the winch through flexible pressure hoses which are coiled up on a drum on the deck when the equipment is not in use. There is a clutch between the hydraulic motor and drum, a pawl system

and a brake in order to stop rotation of the drum, when the net has been set. Before setting the net, the purse wire is wound on the drum of the submersible seine winch, and the end of the wire is connected in the normal way to the net. The submersible seine winch is operated with a special gallows on the starboard side of the vessel, thus the winch is hanging at a separate wire over the railing. When the seine is to be set, the clutch between the hydraulic motor and drum is disengaged, so that the drum runs completely free, and the purse wire runs out in the normal way. At the end of the shooting operation, the end of the wire, which was fastened to the net is now fastened to a swivel-shackle on the submersible seine winch housing. Then the clutch between motor and drum is engaged, the motor started and the submersible seine winch is hanging on the separate wire from the gallows. This wire is connected to the top of the housing of the submersible winch. As the hydraulic motor is now connected to the wire drum, the winch is lowered, and begins to haul in the wire purseline. The submersible pursing winch is allowed to sink below the purse rings, and therefore the pursing is done at the greatest possible depth.

An important point has to be noted in connection with this new development. The purselines for medium size purse seines are 2¾ in–3 in wire, and more than 3000 ft long. This wire size and length could not be wound on the drum of a submersible pursing winch unless it were of very great dimensions, similar to a deck-mounted pursing winch. Due to the direct pull on the purseline below water, 1½ in diameter of the usual length is sufficient, except for the very last end of the wire, which has to be much stronger, as at the end of the pursing operation, the gathered rings will all be concentrated at the wire end, which was set first. When hauling up, it is necessary to lift winch, wire, lead and rings altogether in one operation. This means a very great strain on this part of the purse wire.

By reading an oil pressure gauge on deck it can be seen when the net has actually been closed below water. To prevent the purse wire from going slack again after pursing, the drum on the submersible winch is fitted with a pawl system.

The submerged pursing winch has so far only been tested on purse seines of 50 fm depth, on a Norwegian vessel. If the method will be effective for purse seines up to 100 fm depth, it has great advantages, as the closing of the net is achieved more effectively than with the method now in use, and for new ships this development should certainly be considered. If further practical experiments show that more effective and quicker closing of the purse net has the same effect as a considerably deeper net, the new equipment will certainly be of great importance.

POWER BLOCKS AND NET WINCHES

J. Jakobsson (1964), described the first use of power blocks on Icelandic fishing vessels.

The Puretic power block was introduced in the American Pacific purse seine fisheries in 1954 and 1955, and during the winter of 1956, an Icelandic herring captain, Mr. Ingvar Pálmason, went to the Pacific coast to study this new equipment in action.

Experimentation with the power block started in the Icelandic herring fishery in 1957. The difficulties of transferring this instrument to the Icelandic fishing fleet were due to the different type of vessels used in the Pacific and Icelandic waters. The conventional Icelandic type fishing vessels have a forecastle forward and the wheelhouse aft of amidship, and either a short open deck space aft or a boatdeck to the stern. The Pacific type vessel on the other hand has a long deck house forward and open main deck from nearly amidship to the stern, using a boom on the main mast for suspension of the power block. It was therefore not until the summer of 1959, that Captain Haraldur Ágústsson, on the 95 ft fishing vessel *Gudmundur Thordarson*, carried out successful experiments by shooting and hauling the seine net from the boat deck level aft of the wheelhouse. The Puretic Power Block was hung from a life-boat type davit at the starboard side of the vessel, and this place has since then generally been used on Icelandic fishing vessels, although great developments have taken place in the equipment itself and its auxiliary facilities.

The power block and its davit has slowly been developed into a more or less combined instrument. In some cases hydraulically operated cranes, and also a net winch on the boat deck, with different numbers of rollers, which can be turned and inclined into different positions with power from hydraulic cylinders are used. The turnable rod for the purse rings, the end buoy and the large float to take the main weight of the heavy purseline off the buoy, are still used in the same manner as before.

After the herring schools gradually developed the habit of staying deeper every year, the depth of the nets had to be increased. The deeper and heavier nets required bigger vessels, and thus the smaller herring fishing vessels were forced to quit the herring purse seining, and to convert to other purposes.

With the further increase of the size of nets, the increased weight and space requirements on top of the boat deck the stability of the even bigger vessels was endangered.

To increase the space, and lower the centre of gravity, the aft end of the boat deck was removed and space added on the main deck abaft of the deck houses for storage of the net. Although some form stability was lost this way, the better weight stability was in this case increased. Generally this solution has been a success in practical use, in spite of the very deep net storage aft, having a very high "bulwark" up to about 2.5 m.

This moving aft of a great part of the seine net storage on the vessels resulted also in the need for additional equipment to handle the net. Most of these vessels had to be fitted with a hydraulically driven transport roller, to carry the net from the power block/net winch, to the net storage space aft. This transport roller has usually been hung from a special boom on the aft mast, or on a special mast aft on the port side of the boat deck.

Power block and net winch types

The first power block used in Iceland was the original Puretic power block, hanging free from a davit on the boat deck. The special V-form roller was coated with a layer of rubber. Further developments of this type of power block has been to fit the block on a hydraulically

operated crane, so that both turning, lifting and inclining the block could be done mechanically. This made hauling of the net safer and less manual work was needed. Later came the addition of a press roller to push the cork line against the netting on the back side of the power block.

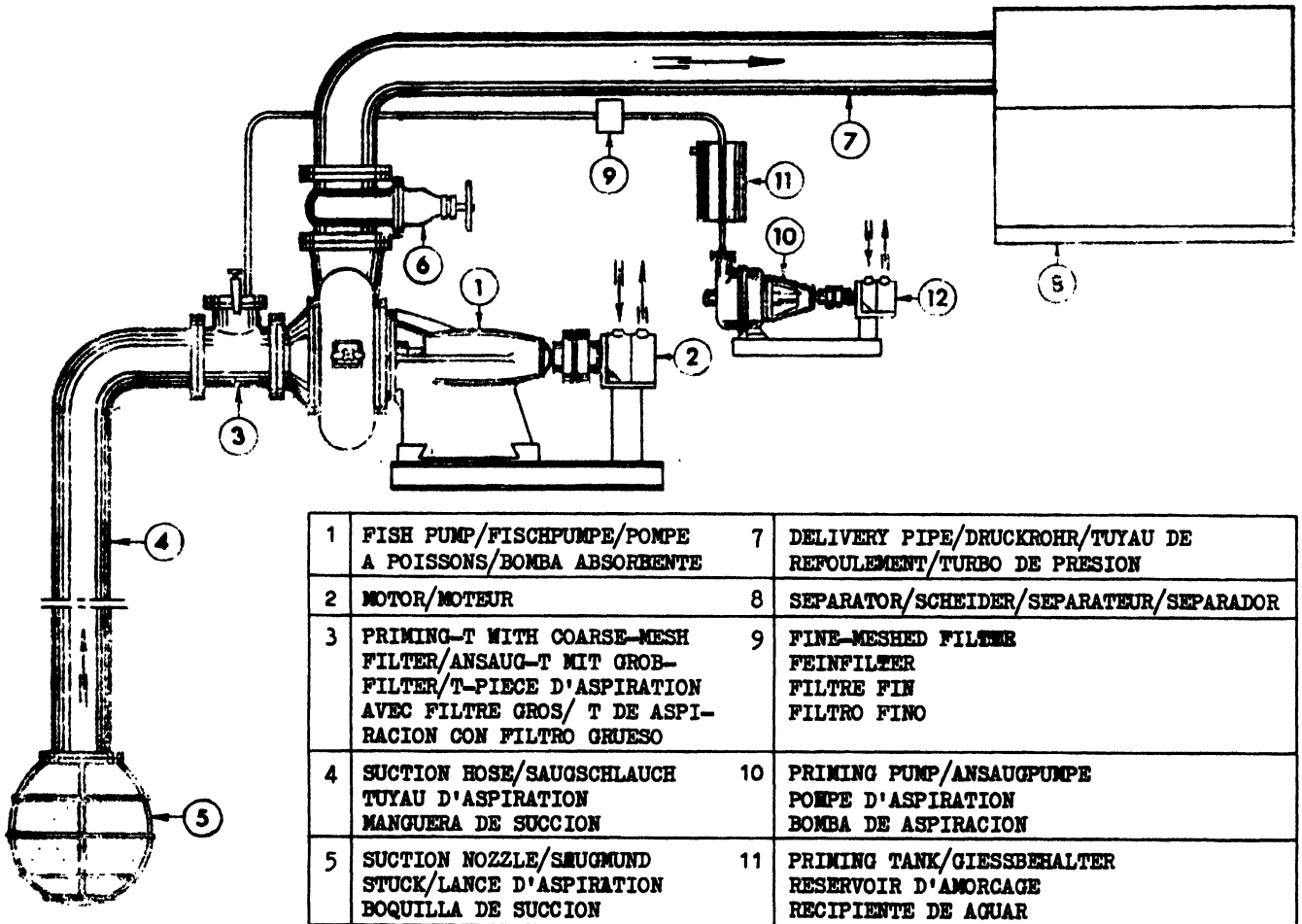
A further step taken was to alter the installation of the powered block roller by setting up the whole equipment on to a foundation on the forward starboard corner of the boat deck. These types of powered block systems have been called also purse seine net winches, or just net winches. They have two or three rollers, usually hydraulically driven, but as rare exceptions some are also electrically driven. The shape of the rollers also varies. Instead of V-shape, a cylindrical shape is used, e.g. when three rollers are combined. A detailed description of each of these systems would take too much space. Generally the net winches have a lower centre of gravity than the hanging power blocks, but a special strengthening of the boat deck structure is needed for installation on existing vessels.

OTHER AUXILIARY EQUIPMENT

Although the brailing operation with the hydraulically operated swinging-boom combined with a separate brailing drum on the seine winch operated by one man has developed to a very efficient technique, the interest in fish pumps for emptying the nets has increased.

The first fish pumps were of the deck-mounted system (fig 3). The pump was placed either directly on deck, or inside the forecastle. A flexible rubber suction hose was lowered into the purse seine, after it had been dried up in the normal way. The discharge rubber hose was then lead to a fish/water separator and the fish from there guided to the hold. For this type of fish pump, a certain space is needed for the fixed mounting either on the open deck or in the forecastle, and the system is connected to a priming tank to start the pump. As an indication of the capacity of these pumps, a 10 in fish pump can pump 500 m^3/h of a water/fish mixture, containing on average 200 T of fish, and a 12 in version pump 750 m^3/h of a water/fish mixture, containing 300 T of fish. Power needed is 26 hp for the 10 in pump and 38 hp for the 12 in pump.

Another type of pump has been designed as a separate, unmounted piece of equipment, which can be carried anywhere on deck and is lowered into the net. This is an hydraulically driven submersible fish pump (fig 4) of 10 in and 12 in size. It pumps approx 500 and 1000 T/h of a fish/water mixture with the 10 in and 12 in version respectively. The amount of fish actually contained in



1	FISH PUMP/FISCHPUMPE/POMPE A POISSONS/BOMBA ABSORBENTE	7	DELIVERY PIPE/DRUCKROHR/TUYAU DE REFOULEMENT/TURBO DE PRESION
2	MOTOR/MOTEUR	8	SEPARATOR/SCHEIDER/SEPARATEUR/SEPARADOR
3	PRIMING-T WITH COARSE-MESH FILTER/ANSAUG-T MIT GROB-FILTER/T-PIECE D'ASPIRATION AVEC FILTRE GROS/ T DE ASPIRACION CON FILTRO GRUESO	9	FINE-MESHED FILTER FEINFILTER FILTRE FIN FILTRO FINO
4	SUCTION HOSE/SAUGSCHLAUCH TUYAU D'ASPIRATION MANGUERA DE SUCCION	10	PRIMING PUMP/ANSAUGPUMPE POMPE D'ASPIRATION BOMBA DE ASPIRACION
5	SUCTION NOZZLE/SAUGMUND STUCK/LANCE D'ASPIRATION BOQUILLA DE SUCCION	11	PRIMING TANK/GIESSBEHALTER RESERVOIR D'AMORCAGE RECIPIENTE DE AGUAR
6	VALVE/VENTIL/SOUPAPE/VALVULA	12	MOTOR/MOTEUR

Fig 3. Example of a fixed installation type fish pump system

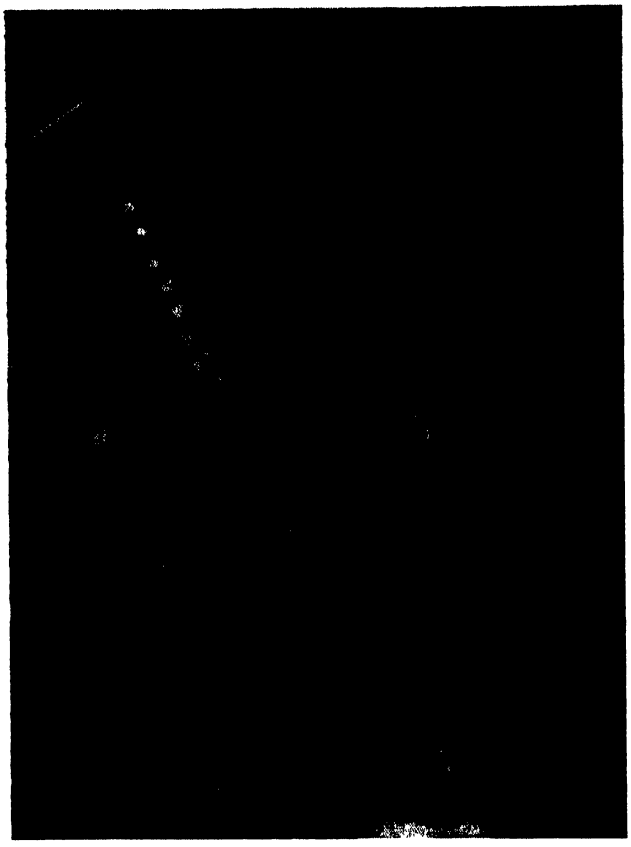


Fig 4. Submersible fish pump on Icelandic purse seiner Eldborg, *being lowered into the net*

this mixture varies, depending on how much the nets have been dried up, but an average figure is about one-third fish, two-thirds water.

Another feature of the submersible type of fish pump is that there is no need for the rather heavy and bulky rigid suction rubber hose because the pressure hose can be of much thinner material and is therefore more handy.

The fish/water separating equipment has also been subject to developments, and a lot of different designs exist. Generally the fish passes over a grid of bars, usually in a C-shape path, but in some cases in a S-shape path. The size of the screen has, of course, to be suitable for the size of fish concerned.

A third type of fish pump is the vacuum pump, of which different designs are available. Although these pumps can also be used to pump fish with water from the nets, the main use of the vacuum fish pumps has been for pumping the dry fish from fish holds, without adding water, into fish carrying cargo vessels or tankers on the fishing grounds, or for unloading fishing vessels or fish carriers in the harbour.

HYDRAULIC SYSTEMS AND REMOTE CONTROLS ON PURSE SEINERS

Hydraulic systems have been described in detail elsewhere. Since most of the equipment for operating purse seiners is today hydraulically driven, a short summary of the main facts might be of interest in so far as it is directly related to the equipment and also in view of the increasing interest in remote control systems.

There are different opinions about the ideal pressure of the hydraulic systems in purse seining. Low pressure systems (about 30 kg/cm^3) are very quiet in operation, which is a very desirable feature for a herring purse-seiner. The hydraulic motors are of low speed, and therefore usually no gears are required between the motor and the equipment to be driven. The low pressure systems are also considered to be very reliable, but large size piping and valves are making the system space-consuming and very heavy. A common piping up is to connect several winches or other equipment in series, so that oil is flowing first to one winch, then to the next etc., and from the last back to the circulating pressure pump.

The so-called high pressure systems, which actually are more correctly classified as medium pressure system (70–140 kg/cm^2), have a great advantage, in that much smaller piping and valves can be used. The greatest advantage is the small size and weight of the hydraulic motors, piping and valves. This makes possible an application of hydraulic power to drive different equipment wherever needed. If the hydraulic oil in the system is maintained clean at all times, the reliability and performance of the medium pressure hydraulic system should be no problem.

The control of hydraulic power systems is well known to be one of the greatest advantages. There is a stepless speed control from stop to the full speed and by controlling the maximum pressure in the system with a relief valve, it is easy to limit the maximum force available. In this way winches and cables can be protected against overload, as the winches can be set at a constant maximum force. To avoid excess heat and noise in the piping system, it is advantageous to keep the pipe and valve dimensions somewhat bigger than would be absolutely needed for the system.

One of the great benefits derived from a hydraulic power system is the possibility of remote control of winches and other hydraulically driven equipment. The drums on winches can have hydraulically actuated brakes and clutches, remotely controlled from a central control console, and also be provided with control valves for all stations of operation. On a single control console can be fitted any convenient number of remote controls for the hydraulic system, for controlling different winches, boomswinger, topping winch, power block etc.

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Application of Drum Seining in the Californian Wetfish Fishery

F. J. Hester

Application de la méthode de seinage avec tambour

Le Bureau des pêches commerciales des Etats-Unis et le Comité de la recherche marine de Californie ont entrepris des essais en vue de l'introduction du tambour dans le pêche à la seine coulissante du poisson industriel en Californie, pour tenter de réduire les coûts opérationnels et les besoins en main d'oeuvre. On prévoit que l'application du tambour aux grandes seines à sardine, maquereau, anchois, bonite et thon, donnera quelques problèmes. Le coût de la transformation (sans le montage du tambour sur une table tournante) s'élève à 29.800 $ US. Une anticipation des parts respectives du navire et de l'équipage montre que ce dernier doublerait sa part, tandis que celle du navire resterait la même, ce qui laisse peu de place à une initiative de transformation. Pour que celle-ci puisse réussir, il faut convenir de nouveaux barêmes de partage des gains de l'équipage et du navire.

Empleo de carreteles para redes de cerco en la pesca para la reducción en California

La Oficina de Pesca Comercial de los Estados Unidos y el Comité de Investigaciones Marítimas de California participan actualmente en experimentos para aplicar el carretel en la manipulación de redes de cerco de jareta para la captura de especies industrialisables con objeto de reducir los gastos de explotación y las necesidades de mano de obra. Se anticipa que planteará algunos problemas la aplicación del carretel a los grandes artes que pescan sardina, caballa, anchoa, bonito y atún. El costo de la transformación (sin montar el carretel en una plataforma giratoria) es de 29.800 dólares de los Estados Unidos. Una proyección de las partes tripulación-barco indica que la marinería duplicaría su parte, pero la del barco continuaría siendo igual lo que no estimularía la transformación. Para que tenga éxito esta pesca, se tienen que negociar nuevas partes para el barco y la tripulación.

IN the U.S. fishing industry, fish must compete with other foods such as meat or vegetable products and with imported fish. Costs must be kept competitive by increasing productivity, that is, the output per man hour. In many fisheries the output per crew man has been raised by modernizing and mechanizing fishing vessels and fishing fleet operational strategies. It can be argued that such technology will be quickly adopted by competitive countries; this may not always be true. If costs of building, equipping and maintaining advanced fishing vessels are comparable in most countries then the owner has to weigh cost of mechanization against cost of labour. In developing nations the decision may well be to use manpower rather than machinery especially if high employment in fishing is a national goal even at the expense of efficiency.

WEST COAST WETFISH SEINERS

The traditional American west coast seiner is based on our highly successful sardine (pilchard) boats of the 1930's and 1940's. These boats are 20 to 30 m long overall and can carry 80 to 100 T of uniced, unrefrigerated fish. The house is forward, and the net is fished from the stern. The boats are used in a canning and reduction fishery for mackerel, herring, sardines, squid and anchovy with some seasonal effort on tuna and bonito. This diversity of species requires that each boat have two or three nets; one for anchovy, one for mackerel, and one for tuna and bonito. Gross dimensions of any of these nets would be 400 to 500 m length by 50 to 80 m depth, mesh and twine size varying according to the species fished.

The vessels use a large power skiff (typically $4 \times 7 \times 1$ m, 100 to 160 hp) to help during the fishing operation. Minimum deck machinery include a pursing winch and a hydraulic power block. Brailing fish from the net to the hold was done with a dip net until recently when Marco[1] hydraulic fish pumps made an appearance.

[1] Use of trade name does not imply endorsement by the Bureau of Commercial Fisheries.

Crew requirements for these boats are for 9 or 10 men including a captain, engineer, mastman, skiffman, and cook, all of whom may help with the gear as needed. These men share-out according to a settlement agreement whereby the net proceeds (gross revenue minus trip expenses such as food, fuel, lube oil, licences, etc) are divided between vessel and crew in a fixed way. For a 100 T vessel, the boat's share is 39.5 per cent, the crew's 60.5 per cent. This share-out scheme is inflexible in the sense that running with a temporarily smaller crew does not increase the vessel's share. There are indications that this situation can be changed if mechanization allows a marked and permanent reduction in crew. Present practice requires at least eight men to stack the net and to brail. If these two operations can be mechanized, a reduction in crew can be achieved.

The seine drum

The seine drum (Pilkington Seine Drum) is a Canadian invention for handling the purse seine. Seine and purseline are wound on to a powered drum instead of being stacked conventionally. Drum seining has been successful on salmon and herring by Canadian and American boats but has not been too popular in U.S. because legal restrictions limit its use in Alaskan waters. Its success on herring suggested that the method should be adaptable to other species. Accordingly, the Bureau of Commercial Fisheries and the Marine Research Committee of the State of California are presently undertaking a test of drum seining primarily for anchovy but also for mackerel if the opportunity arises. The vessel used in the experiment is the M/V *Sunset*, LOA 25 m, CAP 130 T. On this vessel we are installing an aluminum drum 2.4 m in dia and 4.3 m wide with a 0.6 m dia core. The drum was designed and constructed by Post Point Marine, Inc., Bellingham, Washington. This drum is directly coupled to two Kayaba "Hydrostar" medium pressure, constant torque piston motors, which will deliver 1,300 kg m of torque each over a 0 to 100 rpm speed range. This system will provide sufficient speed and power to handle the net under most fishing conditions. In addition to the drum,

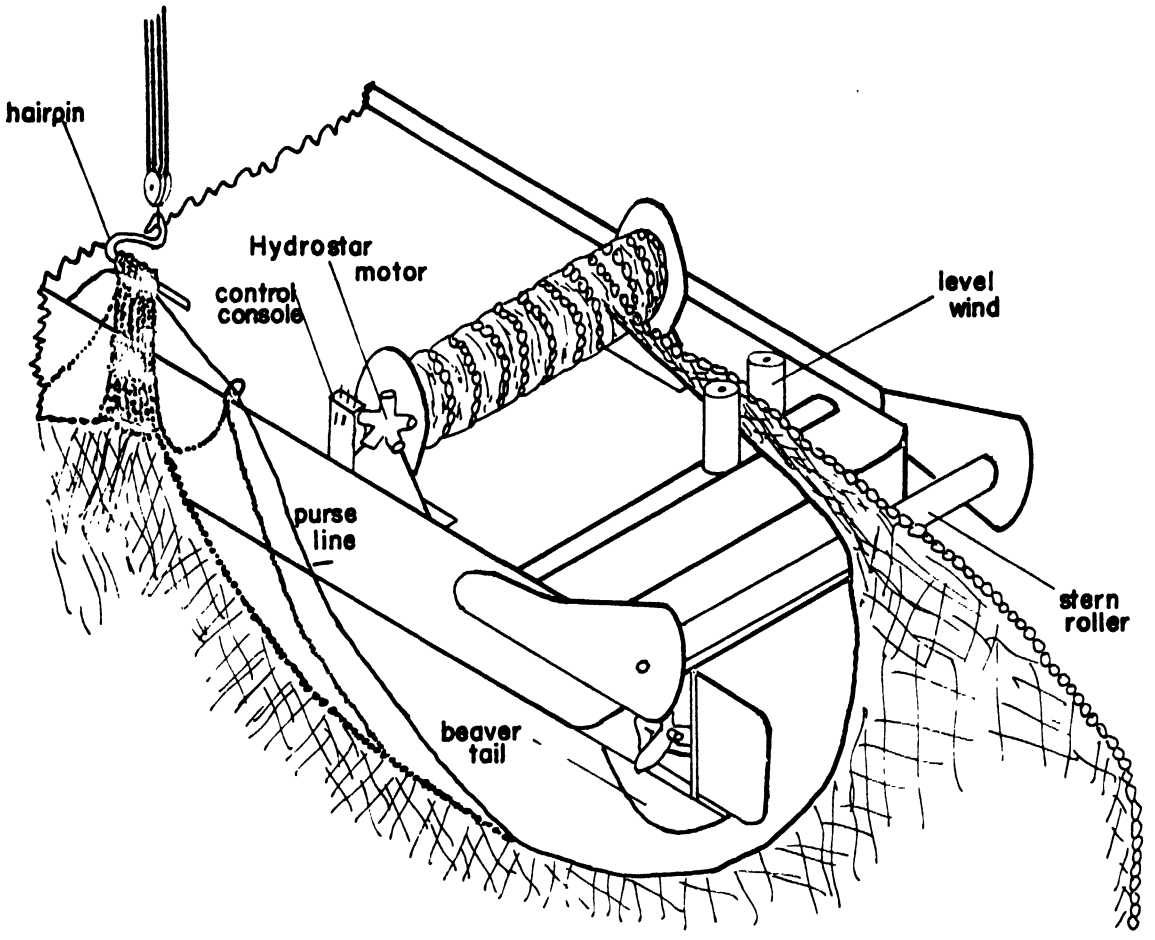

Fig 1. Diagrammatic layout of a drum seine installation

other modifications to the *Sunset* include installation of a stern roller and level wind, an auxiliary engine and large capacity hydraulic system, a 25 cm Marco Capsul-pump, a purse ring "hairpin" (fig 1), a "beavertail" guard for the propeller and rudder, and a reinforced brailing and cork boom.

DRUM SEINING

The operation of a seine drum is the same as that of a regular purse seine with one exception; since the net is stored on a drum the purseline must be wound on the drum along with the net, and enough towline must be wrapped onto the core to allow for maneuvering the boat after the net has been set. Aside from this, the operation is simpler and faster than the conventional method using a power block. The net is set with the help of a seine skiff or a drogue. Once the circle has been completed, pursing can proceed in the normal manner from both ends or, if desired, the net can be pursed from the bow end while the other end is being wrapped onto the drum. Regardless of the method used, once the rings are up they are put on the "hairpin" (fig 1) or on a ring stripper and the purseline is left threaded through the rings. Then, as the net is retrieved with the drum, the purseline (under tension) and the rings are wrapped up with the net. As the net is retrieved, the stern of the boat tends to swing around in a circle until the net is almost all in. Towards the end of hauling, the power of the drum can be used to dry up the fish, and if the bunt (fish bag) is properly tapered the fish can be brought up ready for the pump. At this stage the net runs from the stern roller under the counter, and the bag is formed along the side in the usual manner.

Problems

There are several problems associated with drum seining, but none are considered serious:

(a) At the beginning of the retrieve, the drum is empty except for the towline. In order to bring in the towline at a reasonable speed it is necessary to have a large capacity hydraulic system (the one on the *Sunset* delivers 380 l/min at 140 kg/cm^2). This much capacity is expensive.

(b) The first part of the net to go onto the drum is subject to great pressure because of the small diameter of the drum and because of additional layers of net wrapped on top. Consequently, there is considerable breakage of corks at this end. This breakage can be cut down by using stronger but more expensive corks and by hanging the corks on a separate corkline loosely laced

to the main corkline so that tension on the line through the corks is eased.

(c) Because the purseline is left threaded through the rings there is a danger of kinking the purseline when stranded rope or wire is used. This can be alleviated by using swivels on the purseline or using a braided synthetic rope for the purseline. Nonetheless, it is sometimes necessary to run out the purseline to free it of twists.

(d) One problem that plagued early drum seiners was backlash. Before direct drive hydraulic motors were available the drum was was allowed to run free, with some tension applied by a footbrake. Unless the brakeman was alert, the drum would sometimes over-run the net and become fouled. With the hydraulic systems used today, the drum is always running against a tension of about 100 kg, so that braking is automatic. Backlash, if it occurs, now is usually caused by something caught in the webbing.

(e) On most seine drum installations the drum can be swiveled from side to side, an expensive refinement in large installations. When it is lacking, the radius in which the boat can turn must be restricted, or the net may tangle. This difficulty can be avoided by the skipper, once he is familiar with the limitations of the gear.

(f) On a stationary drum installation, when the net is nearly aboard, the webbing runs under the counter near the propeller and rudder, and there is a good chance of fouling. Drum seiners (and regular seiners) in the Northwest have found it advantageous to put a guard or "beavertail" under the propeller (fig 1) to keep the net clear.

(g) There is probably an upper size limit on the drum, which makes installation impractical on large seiners. Once the diameter of the drum gets much bigger than 3.0 m, the forces may become unmanageable. Then too, the speed of setting should be kept down to limit the rotation speed of the drum. This is no problem on smaller boats but may handicap larger, faster vessels. Finally, the reduction in crew size allowed by drum seining may not hold for distant-water seiners where a large crew is needed to run the vessel, repair the gear, and handle the fish.

Advantages

The biggest advantage of the seine drum lies in the greatly reduced crew needed to man the vessel. Even with a power skiff, the operation can be handled by as few as four men. In addition, the drum can haul the net nearly twice as fast as a power block, and the elimination of overhead handling increases crew safety and comfort.

COST AND RETURN ON INVESTMENT

The seine drum installation on the *Sunset* costs approximately U.S. $30,000 (see Table 1). Reductions from this amount are possible depending on existing vessel equipment and size of the drum; however, this should be a realistic figure to work with. Assuming that the investment is amortized over 5 years and that financing costs run 15 per cent, the yearly cost will be U.S. $6,000 plus U.S. $900 interest or U.S. $6,900. Under the present vessel-crew share arrangement there is little incentive for the owner to make such an investment. If, however, share-out schedules could be renegotiated, this situation could change (Table 2). From the table it is apparent that between the 45/55 and 50/50 split there is negotiating room to reach a division that will benefit both owner and crew.

TABLE 1. COST OF 2.4 × 4.3 m ALUMINUM DRUM INSTALLATION

	$U.S.
Drum with controls, hydraulic motors, level wind, and stern roller	17,000
Hydraulic system 380 l/min pressure pump, hoses, volume tank, and control valves	4,000
Diesel auxiliary	2,500
Beavertail	800
Installation	3,500
Miscellaneous (corks, purseline, etc)	2,000
	$29,800

TABLE 2. ECONOMICS OF DRUM SEINING[1] (IN THOUSANDS OF U.S.$)
Annual vessel gross = $100, trip expenses = $10, net proceeds = $90

	Conventional seining with 10-man crew		*Drum seining with 5-man crew*					
Share arrangement	*Boat* 40%	*Crew* 60%	*Boat* 40%	*Crew* 60%	*Boat* 45%	*Crew* 55%	*Boat* 50%	*Crew* 50%
Share	$36	$54	$36	$54	$40.5	$49.5	$45	$45
Owner's costs[2]	$23		$23		$23		$23	
Drum cost			$6.9		$6.9		$6.9	
Profit before taxes	$13		$6.1		$10.6		$15.1	
Crew share/man		$5.4		$10.8		$9.9		$9

[1]Based on Economic Study of San Pedro Wetfish Boats, William F. Perrin and Bruno G. Noetzel, 1970. *Fishery Industrial Research* (in press).
[2]Includes insurance, taxes, interest, supplies and netting, depreciation, and miscellaneous.

Influence of Vessel Noise on Behaviour of Herring

K. Olsen

Influence du bruit du navire sur le comportement du hareng

Les pêcheurs ont observé que le bruit du navire a un effet défavourable sur le comportement en banc du hareng atlanto-scandinave adulte quand on pêche à la seine coulissante. D'après ce qu'on sait actuellement sur les possibilités d'ouïe du poisson et sur les caractéristiques du bruit du navire, on conclut qu'un effroi temporaire des bancs de harengs est probable.

Influencia de los ruidos de la embarcación en las reacciones del arenque

Los pescadores han observado que el ruido producido per las embarcaciones influye negativemente en las reacciones de los bancos de arenques adultos de la parte escandinava del Atlíántico durante la pesca con artes de cerco. De acuerdo con los conocimientos actuales sobre la sensibilidad auditiva de los peces y las características del ruido de las embarcaciones, se concluye que es probable una dispersión temporal de los bancos de arenques.

SUCCESSFUL purse seining is very often dependent on a "friendly" fish behaviour. In the 1968 summer fishery for Atlanto-Scandian herring in the Bear Island area, behaviour problems adversely affected fishing success. Throughout a great part of the season, herring schools frequently made sudden and extensive downward movements which made purse seining rather hopeless.

Similar experiences have been reported in other years, but in 1968 the problems were increased by the special hydrographic situation which prevailed in the area. From the surface, down to a depth of several hundred metres, small differences in temperature and salinity were found. This may eliminate any particular barriers or hindrances for vertical movements of the fish. There are, accordingly, many reports of schools which descended 150 to 200 m within 1 min.

Fishermen suggest that this strange behaviour was caused by noise from the vessels. They also suggest that this is not only a temporary phenomenon, but a consequence of conditioning to noise which has occurred over a period of several years of continuous fishing.

The scaring effect by vessels seems to result in reduced fishing efficiency. For some purse seiners the consequences were especially severe since there is a difference in the scaring effect between individual purse seiners. Several important aspects of noise influence, therefore, should be seriously studied.

Sudden changes in fish behaviour is normally a result of received sensory impressions. In reactions observed in the vicinity of fishing vessels both visual and hearing impressions may have participated. However, on many occasions the schools were located 20 to 40 m below the surface and far away from the vessel when the reaction occurred. In such a position a distant visual impression of the vessel should not be possible and vessel noise alone should be responsible.

A more objective approach to the problem is to consider existing knowledge about vessel noise, its characteristics and usual ways of generation. By comparing the knowledge of capacities of detection with the reaction by fish, some useful information might be gained.

Characteristics of vessel noise

Noise from a common Norwegian purse seiner (300 to 500 t), recorded 100 m from the vessel running at full speed, will reach an overall level of 30 to 35 dB/1 μBar (20 to 10,000 Hz bandwidth). A frequency distribution of such noise analysed in octave band is shown in fig 1 (average of 10 purse seiners). The noise is dominated by low frequency components and falls off at higher frequencies.

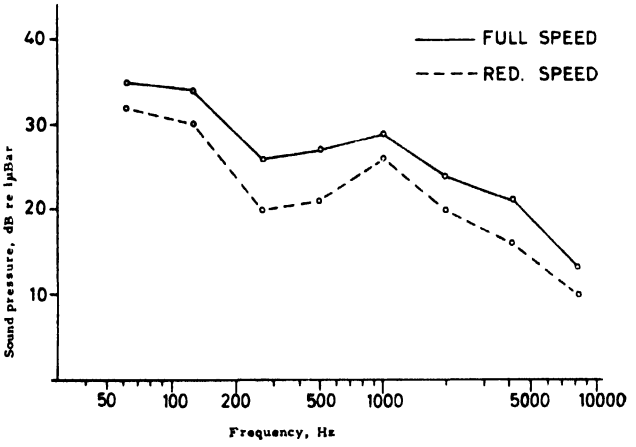

Fig 1. Average frequency distribution of recorded noise from 10 purse seiners (octave band, 100 m distance)

When a vessel is approaching at full speed, the noise level increases about 6 dB each time the distance is halved. At reduced speed (6 to 8 kn) the total noise output is considerably less, especially in the lower frequency range, e.g. in a band around 100 Hz the noise level will usually be reduced about 10 dB.

The various contributing sources result in a characteristic noise pattern from a vessel in a given situation. In this pattern, numerous interference and resonance phenomena will occur. Each source has a frequency response which changes with the mode of operation, and manipulations with dominating noise sources, e.g. changes in engine revolutions, the pitch of the propeller and sometimes the rudder position will consequently alter the noise picture considerably. A change of pitch at medium speed from 1/1 to 1/4 ahead, may for example increase the noise level in the 100 Hz band by more than 6 dB and a further pitch change to 1/4 astern, may increase the level an additional 10 dB. An operation of the rudder is observed to have given an increase of about 6 dB, especially at higher frequencies (500 to 1,000 Hz). Accordingly, these conditions are very important as they show great differences in noise generation from the vessel during a particular purse seine set. Special atten-

tion should be drawn to the noise peak generated from the vessel when stopping after having finished the net set.

Masking by ambient noise

A detectable vessel noise must always be stronger than the level of background or ambient noise in the corresponding frequency band or often even stronger than the noise level in related frequency bands (masking effects). As the ambient noise level to some extent changes with weather conditions, a variable masking of the vessel noise will take place. Such conditions are illustrated in fig 2 (from Wenz, 1962). It is shown that a change of one unit in the Beaufort wind scale gives a corresponding change of 6 to 8 dB in ambient noise level at frequencies above 100 Hz. However, as wind forces have a less pronounced noise producing effect in the very low frequency range, < 100 Hz (Wenz, 1964), and vessel noise still contains heavy noise components at these frequencies, masking of vessel noise by rough weather will be somewhat limited.

Hearing abilities in fish

In scientific literature, reported evidence of the abilities of fish to detect sound is about 50 years old and refers mainly to laboratory experiments. Recent investigations have shown that reliable data are obtained only when the acoustic environment is controllable. Problems of sound propagations in water, in restricted rooms, shows that acceptable experimental locations will, with few exceptions, only be found *in situ*, and great practical difficulties will be connected with such experiments.

In view of these strict requirements for an experimental environment, only a few common salt water species can be considered to have been critically investigated. Among these are cod, *Gadus morhua L.*, which detects sound between 40 and 400 Hz (Chapman and Hawkins, 1969; Olsen, 1969). Another important species is the herring, *Clupea harengus L.*, demonstrated to detect sound in the frequency range 20 to 10,000 Hz (Hering, 1968; Olsen, 1969).

In the best hearing frequency range the threshold for sound detection seems only to be limited by the level of

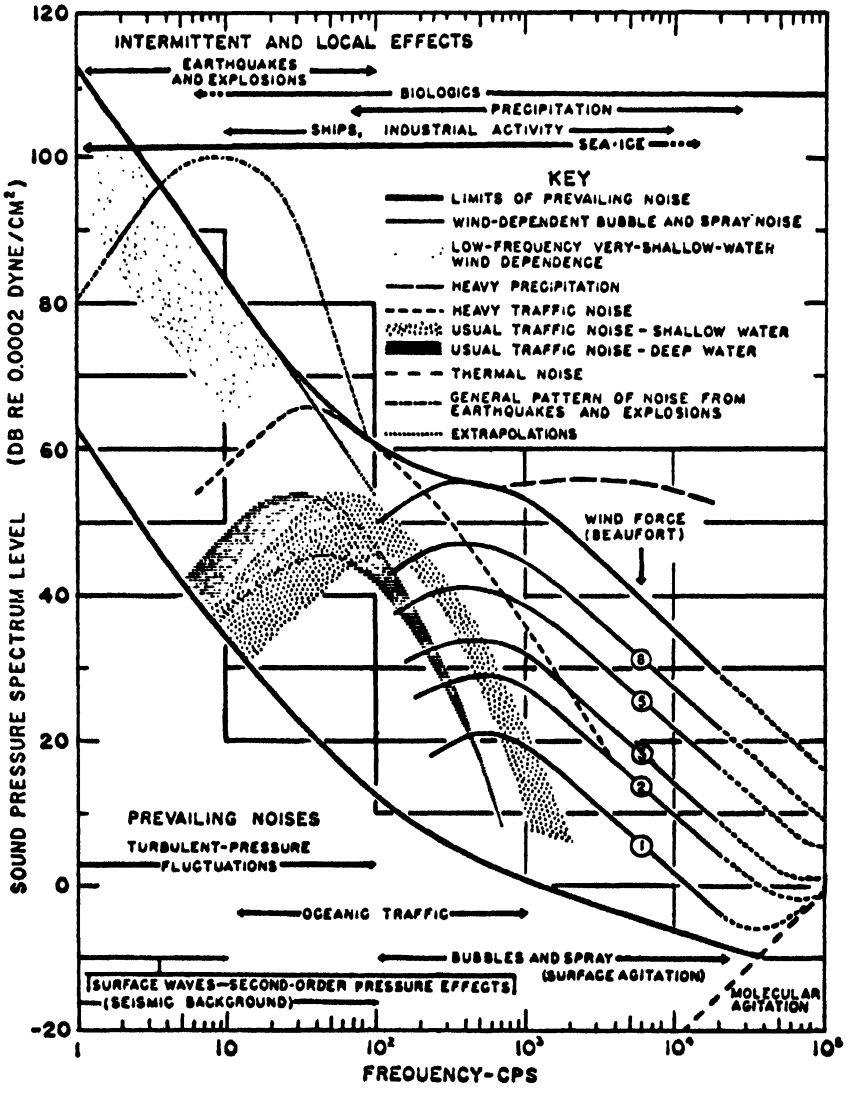

Fig 2. A composite of ambient-noise spectra, summarizing results and conclusions concerning spectrum shape and level, and probable sources and mechanisms of the ambient noise in various parts of the spectrum between 1 cps and 100 kcps. The key identifies component spectra. Horizontal arrows show the approximate frequency band of influence of the various sources (after Wenz, 1962)

ambient noise. Thus, for cod the lowest threshold was determined to be from 25 to 30 dB/1 μBar at 100 to 300 Hz (Chapman and Hawkins, 1969; Olsen, 1969) and for herring at least about 25 dB/1 μBar at frequencies between 50 and 1,200 Hz (Enger, 1967).

The frequency range of optimal hearing in the two species seems to correspond closely with the strong low frequency components of vessel noise. A simple calculation gives a theoretical detection range of a vessel of several nautical miles in calm weather. In practice, however, attenuation reflection, and refraction etc. will reduce this distance considerably.

Evidently the hearing ability in fish is well developed, but to what extent is this sense used by the fish? Any orientated avoidance will also imply a mechanism for directional hearing. The anatomy of the sensory organs for directional determination of sound seems to make this doubtful in many fishes. However, recent investigations have clearly demonstrated directional hearing in e.g. shark, cod and schoools of herring (Nelson, 1966; Olsen, 1969).

With abilities to both detect sound and to locate the direction of the source at a reasonable distance, the fish is sensorily well equipped to utilize acoustic perception in its behaviour. The remaining question is then, to what extent do they really make use of it?

Behaviour to noise

In behaviour experiments on herring (Hering, 1968; Olsen, 1969), small schools of herring showed strong nervous reactions to various noise signals. Typical responses whenever the school was scared, were to break up the school, turn away from the sound source and then later regroup in a new nervously swimming school. After a while, usually less than 1 min, the school relaxed and started slowly circling again.

Interrupted or pulsed signals were shown to scare the schools more than continuous signals, and low frequency signals had a more pronounced scaring effect compared with signals of higher frequency.

These observations being made on herring living in restricted space (net-aquarium in the sea), are nevertheless considered to indicate a pattern of natural behaviour.

There is, however, one important aspect in noise influenced fish behaviour which has not been discussed so far. Above the level of noise necessary for detection is the threshold level for signals which cause a reaction. The relative relation between these two thresholds are controlled by factors which are essential for the discussion, but little is known about the individual significance of these factors.

Parameters such as fish age, maturity, feeding routine, food and hydrographical conditions are evidently influencing the catchability of many fish. Seasonal changes in the behaviour of the fish and even changes from day to day demonstrate this clearly. A good example in purse seining is the capelin (*Mallotus* villosus Müll.) fishery north of Norway. In the spawning season the capelin seem insensitive to any visual or acoustic stimuli, e.g. as those from fishing vessels. During the feeding period the behaviour is far more changeable and much more careful catching tactics have to be applied.

In practical fishing the manoeuvring of the vessel, i.e. the way of "presenting" the noise to the fish, is thought to play a most important role in scaring fish. All manoeuvrings introduce sudden changes in the noise picture, and herring experiments have demonstrated that such a change in noise conditions can be critical. In these experiments the noise signals were generated by underwater sound projectors several metres from the school. The signal level was increased in steps, starting below the level of ambient noise. With a low frequency signal (filt. noise, 100 Hz c.f.) a typical response was obtained at about 20 to 25 dB above the ambient noise level. When varying the stepping programme it was found that a quicker increase in the signal level gave earlier and more spontaneous reactions, and a slower stepping rate had the opposite effect. With a very slow increase of the signal an adaption seemed to occur.

Many fishermen, aware of these difficulties, have improved their net setting technique by keeping propeller revolutions and pitch as constant as possible.

CONCLUSION

The available evidence clearly suggests that temporary scaring of herring schools occurs frequently. This may at times cause considerable problems for fishermen, but the consequences would be much more grave if such frequent scaring resulted in a more permanent nervousness of the herring. This question is very difficult to discuss, but let us for a moment look upon nervousness in fish as some kind of conditioning. Laboratory experiments have shown that cod is able to learn by conditioning after less than five repetitions; for herring such a conditioning technique is extremely difficult and no similar results are known. An interesting experiment, however, would be to reverse the situation. If we assume the nervous reactions to noise to be associated with a source of danger, we could repeat the stimulus for the herring without presenting any danger. Then we could ask, how many repetitions are needed before herring is "conditioned" to forget? In fact this was the technique used in the herring experiments. In the experiments a low-frequency noise stimulus was repeated up to 20 times in a day for a period of several days, but the response was spontaneous flight reactions. This reveals that herring is slow to learn and consequently that "conditioned nervousness" is doubtful. What is also may suggest is that nervous responses to noise signals in a school of herring is some sort of an instinctive reaction—it simply needs no further learning. The short time interval between a scared condition and apparent relaxation in the same schools, seems also to imply an impression of noise scaring being a temporary phenomenon in fish behaviour.

In the late 1950's, when average age of the herring population increased because of little recruitment, the schools were reported to become more and more difficult to catch. Again, an experienced behaviour of the herring may seem likely, but it could also indicate a relation between pronounced noise reactions and age or size of the herring (faster, stronger). Perhaps this explanation could be a fair one too.

Vessel noise with its expressed influence on fish behaviour is still a subject where very little is known. The unfortunate experiences in Norwegian purse seining, especially in the herring fisheries, have started a serious discussion on plans to make a considerable effort to seek practical solutions.

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Effect of Vessel Noise in Purse Seining

Y. Maniwa

Influence des bruits du navire dans la pêche à la seine coulissante

L'influence des bruits du navire est importante dans preque toutes les pêches et en particulier dans la pêche à la seine coulissante. Les bruits de seineurs, d'un navire de recherche et d'un petit bateau de pêche aux lignes traînantes ont été analysés. Les bruits du navire pouvant effrayer ou disperser les bancs de poissons, il est clair que leur atténuation est toujours souhaitable.

Consecuencias del ruido producido por los barcos en la pesca con redes de cerco

Las consecuencias del ruido producido por los barcos son importantes en casi toda la pesca, pero especialmente en la que se efectúa con redes de cerco de jareta. Se analizaron los ruidos ocasionados por los barcos que la practican, por uno de investigación y por otro pequeño para la pesca a la cacea. Como el ruido producido por el barco puede espantar y dispersar a los cardúmenes, conviene reducirlo todo lo posible.

LITTLE attention had been paid to the noise of vessels until it was found that its effect could be serious, especially in purse seining and, in particular with increased engine power, increased revolutions and increased mean effective pressure.

High speed purse seining leads to such strong vessel noise that it sometimes interferes with the operation. For investigating this problem an analysis was made of the noises, and experiments were performed on their effect on the behaviour of fish schools, all of which confirmed that fish schools were sometimes startled and dispersed by vessel noise. It is therefore necessary to devise means to decrease such noises.

Underwater noise of a purse seiner

Underwater noises made by a wooden purse seiner and two steel purse seiners of about 90 GT were recorded on magnetic tape and analysed. The characteristics of the investigated vessels are shown in Table 1.

TABLE 1. CHARACTERISTICS OF THE INVESTIGATED VESSELS

Name of vessel	No. 21 *Hakuryu-Maru*	No. 5 *Hakuryu-Maru*	No. 21 *Taikei-Maru*
Category	85 GT wooden vessel	90 GT steel vessel	90 GT steel vessel
Length overall	23.80 m	25.50 m	30.30 m
Breadth	5.40 m	5.80 m	5.80 m
Depth	2.60 m	2.60 m	2.55 m
Gross tonnage	84.52 GT	about 90 GT	90.56 GT
Main engine			
Category	Hanshin Diesel 6EM	Yammer Diesel 12MT	Niigata Diesel M6F26LS
Brake horsepower	310 bhp	550 bhp	420 bhp
Revolutions per minute	390 rpm	720 rpm	380 rpm
Propeller			
Diameter	1,530 mm	1,750 mm	1,650 mm
Pitch	860 mm	CP	970 mm
Number of blades	3	3	3

Underwater noises were recorded at a distance of 65 m from the vessels while they were stopped and only the engines were operated. Figure 1 shows spectrums analysed by a Panoramic Sonic Analyser. The abscissa shows the frequency (Hz) and the ordinate shows the sound pressure (dB re 1 μBar).

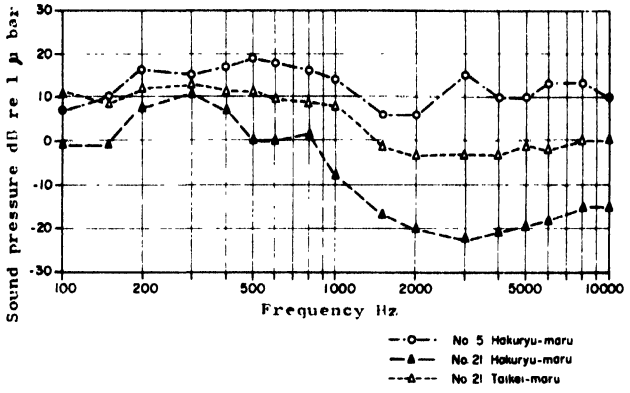

Fig 1. Spectrums of underwater noises produced by the engines of No. 21 Hakuryu-Maru (*wooden boat*), *of No. 5* Hakuryu-Maru (*steel boat*) *and of No. 21* Taikei-Maru (*steel boat*). *The distance is 65 m.*

In the spectrum of No. 21 *Hakuryu-Maru* (wooden vessel), the sound pressure is maximum at 300 Hz and low at the range over 1,000 Hz. The pressure at 3,000 Hz is lower by 33 dB than the maximum. The spectrum of No. 21 *Taikei-Maru* has a similar pattern. The difference in horsepower between No. 21 *Hakuryu-Maru* (wooden vessel) and No. 21 *Taikei-Maru* (steel vessel) is 100 bhp and the revolutions of the engines are approximately the same. But the sound pressure of No. 21 *Taikei-Maru* is higher than that of No. 21 *Hakuryu-Maru*. The difference in the range over 1,000 Hz is more than 15 dB.

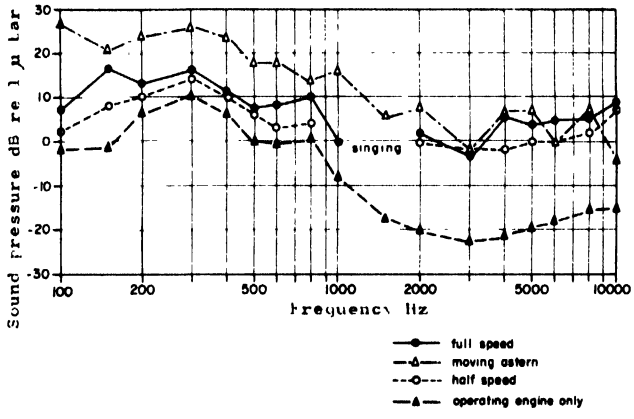

Fig 2. Spectrums of underwater noises produced by No. 21 Hakuryu-Maru *while running; the distance is 55 m.*

Flow noise and other noise produced by the propeller and the hull are added to the noise produced by No. 21 *Hakuryu-Maru* while running. The sound pressure is higher than when operating the engine only, especially in the frequency range over 1,000 Hz. The pressure is higher at full speed than at half speed and much higher in the range below 2,000 Hz while moving astern. The propeller resonated at half speed and full speed. The resonate frequency is 1,000 Hz at half speed and 1,380 Hz at full speed.

The sound pressure of noise of No. 5 *Hakuryu-Maru* is high in the range above 2,000 Hz and approximately the same in the range below 1,000 Hz. The maximum is at 300 Hz. Spectrums are shown in fig 3.

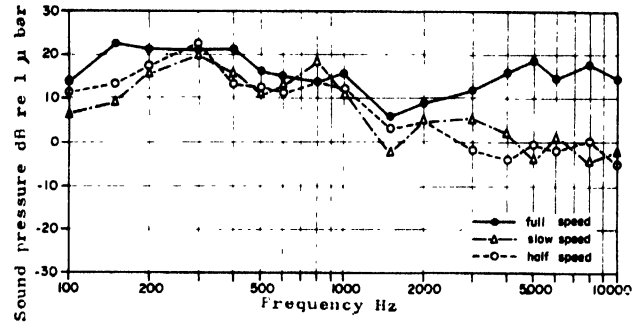

Fig 3. Spectrums of underwater noises produced by No. 5 Hakuryu-Maru *while running at various speeds. The distance is 75 m.*

Noises of research vessel and troller

Noises made by No. 2 *Chiba-Maru* (research vessel) and *Misa-Maru* (small troller) were used for experiments on the behavioural effect on fish schools.

No. 2 *Chiba-Maru* is a wooden vessel of 85 GT with a diesel engine of 275 hp. The revolutions of its propeller are 280 rpm at slow speed and 350 rpm at full speed. Its sonic characteristics were approximately the same as the above-mentioned purse seiners. The spectrum of its noises were measured at a distance of 50 m at slow speed and at full speed (fig 4). The overall sound pressures were 21 dB and 28 dB respectively.

Sonic spectrums of a small troller (*Misa-Maru*) of 4.91 GT with a diesel engine of 35 hp are shown in fig 5.

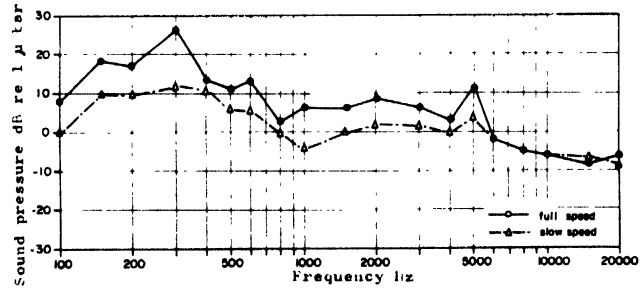

Fig 4. Spectrums of underwater noises produced by No. 2 Chiba-Maru *(research vessel) while running. The distance is 50 m.*

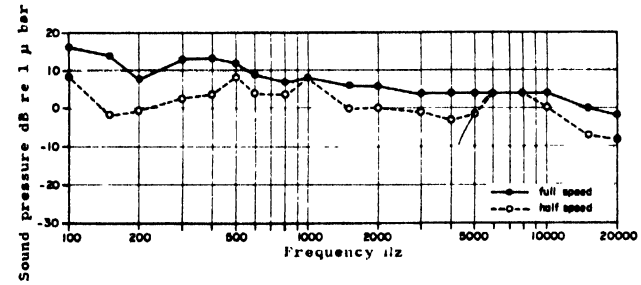

Fig 5. Spectrums of underwater noises produced by Misa-Maru *(small troller) while running. Distance is 20 m.*

Effect of vessel noise on fish behaviour

When hauling up live tuna to the deck of a troller, it begins to act violently as soon as another vessel runs astern in the vicinity. Mackerel, which are gathered by fish luring lamps, are dispersed by the propeller noise when the vessel is shifted. Mackerel pike are startled and dispersed by vessel noise. Catches of hairtail by a diesel engine trawler were less than that of a steam engine trawler engaged in simultaneous fishing operations. Tuna purse seiners were recently changed from wooden to steel construction. There are some instances when catches of tuna by steel vessels have been less than catches made by wooden vessels. One of the reasons may be the difference of transmission of vessel noise into the sea water.

There are, however, some useful applications of vessel noise. One is to prevent fish schools from escaping through the unclosed ends of a purse seine by frightening them with vessel noise. Another example is to frighten and drive fish towards a gillnet.

Experimental investigation on effects of vessel noise

The first experiment was performed on 220 mackerel with a mean body length of 21 cm which were preserved in a fish culturing net in Tateyama Bay, Chiba Prefecture, in September 1968. The ambient sea noise level was 4 dB. The school of mackerel swam slowly clockwise at a depth of more than 2 m. The fish were not startled by the sound produced by sea waves beating on the side of the No. 2 *Chiba-Maru* which was nearby. The vessel noise of No. 2 *Chiba-Maru*, which was emitted by an aqua sound projector at 26 dB, created an obvious fright reaction.

The same experiment was also made with young yellowtail. Before the noise emission, fish swam at a distance of about 50 cm from the projector. They were dispersed by the vessel noise of No. 2 *Chiba-Maru* at 36 dB.

An experiment on schools of *Spratelloides japonicus* (mean body length 7.7 cm) mixed with silverside (*Athernia bleekeri*) was conducted in Tateyama Bay, January 1967. First the fish were settled in a static condition by a fishing light under which they gathered densely at a depth from 7 m to the bottom of 13 m. It was observed on the record of the fish finder echo sounder that they descended as soon as the vessel noise of *Misa-Maru* at 27 dB was applied from above. The noise of the *Misa-Maru* was also tested on Japanese perch-wolf in a tank. The level of ambient noise was 19 dB in the tank. They were startled by the vessel noise of 48 dB, increased their swimming speed and then changed their swimming direction.

Noise and Vibration Aspects of Fishing Vessel Design

D. J. Doust, J. Logan

Le bruit et la vibration aspects de la conception du navire de pêche

Les forces d'interaction qui se développent entre la surface de la carène et une hélice marine sont dues principalement au sillage irrégulier dans lequel le propulseur fonctionne. Il a été démontré que ces forces pouvaient être suffisamment grandes pour produire une vibration de la coque et des installations de la machine. Elle est aussi une source sous-marine de bruit qui peut avoir une influence sur certaines espèces de poissons. L'atténuation du bruit sur les navires de pêche peut être réalisé par une étude soigneuse des différentes parties de la machine et de l'équipement, en accord avec les principes théoriques établis. Les fréquences naturelles de vibration de la carène des navires de pêche peuvent être estimées aux premiers stades de l'établissement du plan. Des exemples pratiques d'isolation vibratoire de parties individuelles de la machine et de l'équipement montrent de quelle manière des montages élastiques et des matériaux absorbant les sons peuvent être efficaces dans la plupart des cas. On démontre que l'atténuation du bruit sous-marin dépend des systèmes constitutifs du bateau, tels que la structure de carène, la machine et les systèmes d'équipement, le tuyautage et le dispositif de ventilation. Un nouveau système "YPASS" de propulsion canalisée et de gouverne a été mis au point pour réduire les problèmes de bruit et de vibration sur les bateaux de pêche. Ces dispositifs de propulsion et de direction sont enfermés complètement à l'intérieur du navire. En raison du courant d'eau régulier et contrôlé dans le système propulseur, de nombreau problèmes de vibration et de bruit associés aux navires de pêches conventionnels sont atténués.

Aspectos relativos al ruido y a la vibración en el diseño de barcos de pesca

Las fuerzas interactivas que actúan sobre una hélice marine y sobre la superficie del barco son debidas principalmente a la estela irregulares en que actúan. Se ha observado que poseen magnitud suficiente para causar vibraciones en el casco y la maquinaria. Estas fuerzas interactivas producen también ruidos submarinos que pueden influir en ciertas especies de peces. La atenuación del ruido en los barcos pesqueros se puede conseguir diseñando cuidadosamente la maquinaria y las partes del equipo, asi como ateniendose a principios teóricos establecidos. Las frecuencias de vibración natural del casco en los barcos pesqueros se pueden calcular en las fases iniciales del diseño. Ejemplos prácticos de aislamiento de vibraciones en la maquinaria y en las partes del equipo ilustran la manera en que pueden ser más eficaces los montajes elásticos y los materiales absorbentes del sonido. La atenuación del ruido submarino depende de los sistemas componentes del barco, tales como la estructura del casco, la maquinaria y equipo, los sistemas de tuberías y de ventilación. Para reducir los problemas ocasionados por el ruido y la vibración en los barcos de pesca, se ha creado un nuevo sistema de propulsión y gobierno llamado "YPASS", el cual va colocado en un conducto. Estos sistemas van completamente dentro del barco. Debido al flujo regular y controlado del agua en el sistema impulsor, se alivian muchos de los problemas de la vibración y del ruido que van asociados con los barcos pesqueros corrientes.

THE interaction of a conventional marine propeller fitted outside the ship's hull surface, with the irregular wake in which it operates, often leads to periodic forces and couples of sufficient magnitude to excite vibration in the hull and machinery. The vertical and horizontal forces originating from the exposed propeller excite hull vibration, whilst thrust and torque variations mainly excite vibration in the machinery, foundations and seatings. The periodic interactive forces which arise from the action of a conventional exposed propeller, working behind a ship's hull, are a prime source of waterborne noise. These forces can also be responsible for additional noise levels within the ship's hull, which are further amplified and dissipated through the external hull surface both below and above the waterline.

Noise attenuation in ships generally, and particularly in fishing vessels, is achieved by (a) careful design of individual machinery and equipment items and (b) attention to certain clearly established principles which have been established through a combination of theoretical and onboard practical experience.

HULL VIBRATION PROBLEM

Several authors have provided excellent accounts of the derivation of the main hull vibration characteristic modes (Johnson and Ayling, 1956–1957; Johnson, Ayling and Couchman, 1962; Aertssen, 1963) to which further reference is recommended. These consist of the two, three and four noded vibrations in the vertical and horizontal planes, and the one-noded torsional or longitudinal vibrations. The sources of vibration which can excite resonant "peaks", at which amplitudes are maximal, are the unbalanced primary or secondary forces in the main machinery, and forces emanating from the external propeller system.

The propeller interactive forces, which can excite all of these vibratory motions, increase in magnitude according to the relative values of the following parameters:

(a) **Peripheral clearances between the propeller and ship's surface:** Increase in these clearances generally reduces the magnitude of the interactions.

(b) **Fullness of after hull shape ahead of the propeller:** Increase in after hull fullness is generally detrimental to performance and beyond a limiting value produces complete breakdown of the hydrodynamic flow into the propeller and rudder system.

(c) **Number of propeller blades:** Increasing the number of blades generally reduces the magnitude of the interactive forces, due to the reduced loading per blade.

(d) **Rudder thickness:** Increase in rudder thickness increases the pressure field ahead of the rudder nose and, therefore, in single screw vessels, increases the magnitude of the interactive forces.

(e) **Ship length:** Absolute ship size affects the thickness of the ship's boundary layer. In cases where the aperture is "closed" it is therefore advisable to increase the clearances of the propeller to avoid interference with this boundary layer flow.

(f) **Propeller section shape:** Singing and vibration can occur with certain propeller section shapes at particular combinations of inflow velocity and rates of rotation.

To assess the relative importance of each interactive force with the main hull predominant frequencies, it is important to be able to estimate natural frequencies of vibration of the ship's hull in the initial design stages. Knowing the dimensions of the vessel, the mean moulded draft and displacement, it is possible to predict the vertical and horizontal two-noded frequencies of vibration of the main hull. The accuracy of prediction of these two frequencies is generally found to be within ± 4 per cent of the measured results for individual ships.

UNDERWATER NOISE REDUCTION

The underwater noise signature of a vessel may be reduced by observing the following guidelines. The cases illustrated are not an exhaustive survey of all the items which might be considered, but are indicative of the type of situation which should be considered. It is strongly suggested that the concept of a "quiet" ship be initiated at the preliminary design stage and carried through the design and construction stages into the operation and maintenance stage. This is not to be construed to mean that improvements to existing vessels are impossible, but only that they are usually more difficult, less satisfactory and more expensive.

In general, noise and vibration should be eliminated or reduced as far as practical, at their source. Where this is not possible, noise and vibration should be isolated and effectively damped.

The hull of the vessel should be designed to be as stiff and as dead as possible. The bottom shell plating should be $\frac{3}{8}''$ thick and preferably thicker. Where the vessel is longitudinally framed, the transverses should be spaced in the order of 4 ft apart. Special attention should be paid to the shell plating panels in the vicinity of the propellers. Large areas of unstiffened plating should be avoided. Where these are unavoidable the plating thickness should be increased, and/or a suitable damping compound applied. "A" bracket, struts etc., should be designed to be free from cavitation for rudder angles up to 15°. All bolted plates, ladders, gratings etc., should be made rattle-free—installing gaskets or washers if necessary.

Machinery and equipment

Component parts of a system and individual machines should be selected for low noise outputs and vibration-free characteristics. Noisy machinery and equipment should be located, where possible, in one compartment and as far away as possible from reflecting surfaces, at least 2 ft from a bulkhead and 3 ft from a corner. The compartment may then be acoustically treated.

Where possible all machines should be fitted with efficient silencers resiliently treated and acoustic hoods used where necessary.

All rotating items should be accurately balanced. Sleeve bearings, being quieter than ball-bearings, should be used where possible.

Pumps and associated piping are a significant source of noise which can be reduced by the following:

(a) Design so that pump horsepower and speed are as low as possible
(b) Keep peripheral speed of pump blades as low as possible
(c) Use multi-stage pumps for high pressure
(d) Pressure pulse variations should be kept to a minimum
(e) Cavitation noises should be avoided by giving due consideration to the net positive suction head
(f) Eliminate line of sight piping between pumps and the sea
(g) Discharge ports should be below the liquid surface
(h) Mount pumps resiliently and isolate hanger rods
(i) Straight-through type valves, such as gate, butterfly or ball should be used where possible
(j) Systems should be designed so that such valves are operated in a fully opened or fully closed condition only
(k) Unsupported ends of piping, either with or without valves, should be avoided
(l) Fluid velocity should be kept low, preferably below 360 ft/min and certainly below 900 ft/min. Short radius pipe bend (below 5 dia) should be avoided.

Ventilation systems

Vibration from this source can be reduced by observing the following:

(a) Round or oval ducts, being stronger and stiffer than rectangular ducts, are more effective in reducing vibration
(b) Thin metal panels of a few square feet or more require to be restrained from resonating
(c) Bell-mouths should be fitted at ventilation inlets. Outlets should have as large an area as possible, preferably through a layer of cellular material
(d) All fans should have a flexible connection (3 to 6 inches in length) to their ducting system
(e) A section of ducting immediately after the flexible connection at the fan should be resiliently mounted
(f) Where a 90° turn exists at the fan inlet or within 6 ft of the fan outlet, turning vanes should be used
(g) All fans should be resiliently mounted
(h) Fan blade tips should be square and their peripheral speed should be as low as possible. The same volume of air may be obtained, with less noise, by increasing the number of blades
(i) All high pressure ducts (5 in S.P. or more) should be isolated from the ship's structure and fitted with turning vanes as necessary

"Y" PROPULSION AND STEERING SYSTEM

To avoid many noise and vibration problems experienced with a conventional propeller exposed outside of the hull surface, a new propulsion and steering system "YPASS" has been developed by Central Design and Drafting Limited, Montreal, Canada. This system has particular application to fishing vessels, which require good tractive effort in the trawling condition coupled with a minimum of radiated noise.

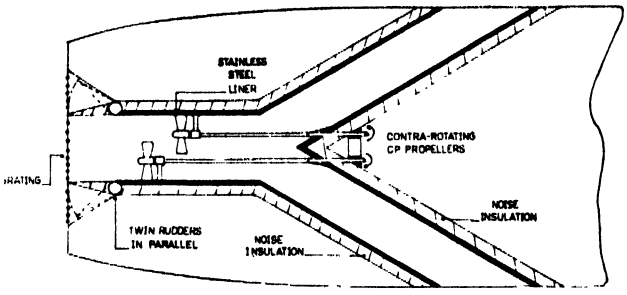

Fig 1. Schematic view of the principle of Ypass system

The basic system is shown in figs 1 and 2. Water enters each lower side duct (fig 1) by means of a specially-shaped hydraulic scoop, and then continues along the longitudinal composite duct. Butterfly valves are located in each side duct, operated hydraulically from the bridge, to give lateral control of the vessel as required.

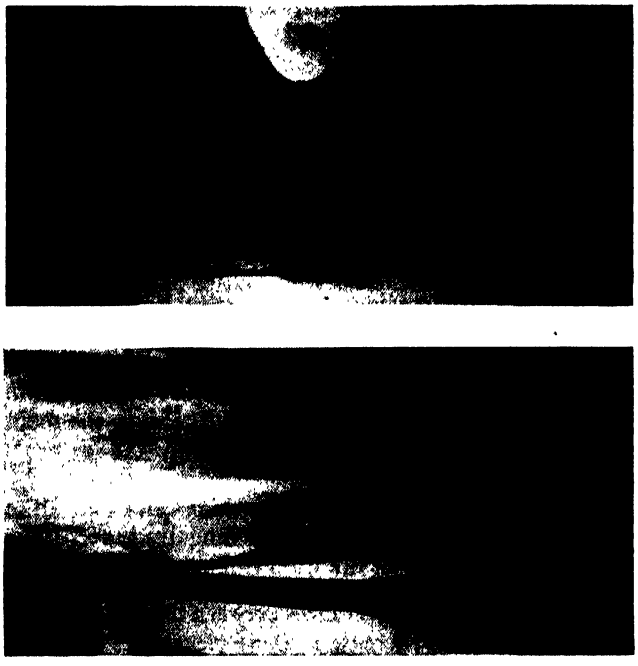

Fig 2. Ypass equipped model; view at the stern (above) and side duct inlet (below)

On entering the composite duct, the water is accelerated into the twin impeller system. Each impeller is separately shafted and driven inboard of the Vee-shaped junction, formed by each side duct. After passing through the twin impeller system, the water is then partially decelerated by volumetric expansion and enters swivelling twin rudders, also controlled hydraulically from the bridge. These rudders work in unison and are wholly contained within the vessel, and protected by a grid from net entanglement.

Provision can also be made for specially-shaped grids to be fitted at the inlets of each side duct, to give maximum protection of the impeller system for ahead motion of the vessel.

Each impeller is operated from the bridge to provide combined pitch and revolutions control as required and the rotation of each impeller is outward when viewed

from aft. The following advantages have been obtained as a result of extensive theoretical studies and tank tests.

(a) Propulsive efficiency is largely independent of the after body shape. As a result, the fullness of most fishing vessels can be increased without adversely affecting the propulsion performance.

(b) Capability of exerting up to 50 per cent of the main thrust of the impellers sideways at the stern of the vessel. Under trawling conditions, to ensure comparable warp tensions on each side of the vessel, a small movement of the swivelling twin rudders is sufficient to bring these into balance. The vessel can also be manoeuvred astern very effectively, an impossible manoeuvre with a conventional SS vessel.

(c) Increased external towing force for trawling purposes can be obtained from the propulsion system. Under bollard test conditions, increased impeller thrust can be obtained up to 80 per cent in excess of that obtained for conventional exposed propellers.

(d) Stopping ability from full ahead to astern is considerably improved. Model tests have indicated stopping distances down to 60 per cent of a conventional propeller system. This characteristic is considered particularly useful in cases when a bottom trawl becomes fast on the bottom.

(e) Propeller induced vibration to the hull structure is minimized due to the controlled and even distribution of water to the impeller system. In light loaded conditions, racing, as experienced with exposed propellers is largely eliminated as there is always water contained in the ducts.

(f) Improved rudder action with frictional losses confined to the inner surfaces of each rudder.

(g) Reduction in shaft torque (≏30–50 per cent) which reduces the scantlings required for all shafts, gear boxes and gearing, due to the fact that the efficiency of all the ducted system optimizes at between 1.5 and 2.0 times the conventional propeller rpm. With

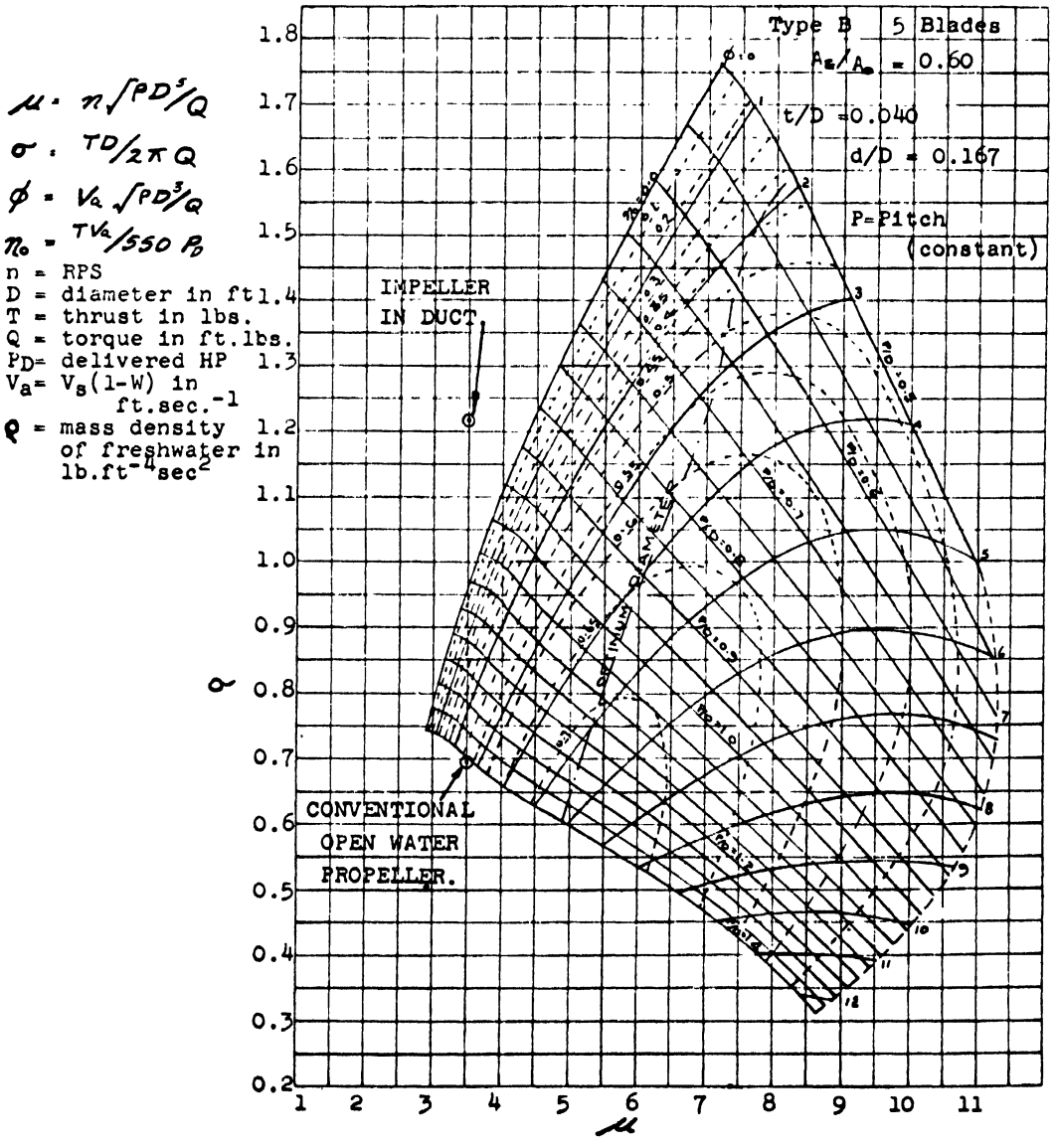

Fig 3. μ–σ diagram screw series B.5.60

suitable choice of machinery, it is possible in some types of fishing vessel to dispense with the gear box entirely. For vessels working in ice, additional reductions in shaft and propeller scantlings are allowed. (Lloyds approval "in principle" has been obtained for this system as well as other Classification Societies.)

(h) Impeller diameters are generally 60–70 per cent of the equivalent open water propeller for comparable efficiences, resulting in reduced first cost and weight of these items.

(i) For some fish species, it has been found important to minimize the noise levels emanating from the main propulsion and propeller system. Due to the configuration of the YPASS system it is possible to insulate the ducts and hence the impellers against detectable noise, external to the ship.

Propeller designers usually make use of design charts similar to the Troost type diagrams, when calculating the performance of conventional propellers under bollard test conditions ("The N.S.M.B." Standard Series Propeller Data). The Troost diagram for a five-bladed propeller of 0.60 Blade Area Ration and a five-bladed impeller of the same blade area and physical characteristics as the Troost propeller, but working in the duct of "YPASS" system are shown in fig 3. The increase in Σ (proportional to the increase in tow pull), relative to a propeller in open water conditions, is approximately 77 per cent. The improvement in tow rope pull for this propeller, working in a nozzle, would be of the order of 30 per cent.

Apart from the specific insulation of waterborne noise external to the internal "Y" duct system, the effect of fitting contra-rotating controllable pitch impellers is to decrease the rotational wake aft. The wake is further "smoothed" by the provision of the grid at the after end of the system, which also gives added protection to the impellers and rudders. This reduction in rotational wake velocity is not only beneficial in reducing the "beat" frequencies, relative to a conventionally exposed propeller, but also reduces the tendency for the fishing gear to be disturbed when shooting the trawl. This tendency for the fishing gear to be "unstabilized" when shooting operations are commenced, has already been experienced with conventional single screw propeller systems, particularly for midwater trawling. Compared with a single screw vessel, the tandem arrangement of contra-rotating C.P. impellers shows advantages in propulsive efficiency of between 5 and 10 per cent.

The description of the "YPASS" System contained herein is in accordance with U.K. Patent No. 29070/69 and patents pending in other countries.

Acknowledgements

The authors express appreciation of helpful advice and suggestions given by Mr. Alan Grundy, Canadian Forces Headquarters, Ottawa.

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Commercial Purse Seining and Trends of Future Improvements

S. S. Torban

Pêche commerciale à la seine coulissante et tendances des améliorations futures

Il est suggéré d'employer des poulies multiples, à point de suspension bas, plutôt qu'un seul power block à point de suspension élevé. On a besoin d'une installation de hissage de puissance considérable pour transférer l'extrémité de proue du filet à la poupe pour la préparation du coup de seine suivant. On expérimente actuellement l'emploi du chalutiers à rampe pour filer et hisser la seine par l'arrière. Dans ce cas, les deux ailes du filet sont virées simulanément. La capture peut être soit embarquée à l'aide d'une salabarde, soit hissée sur la rampe dans un sac semblable à une poche de chalut. On propose l'emploi de pompes à poisson et de systèmes de transfert du poisson pour des opérations de pêche encore plus mécanisées. Des treuils concus spécialement pour la seine coulissante sont préférables à une disposition polyvalente. Le treuil de seine submersible donne de belles aspérances pour l'avenir.

Pesca comercial con artes de cerco y mejoras futuras

Se sugiere que en lugar de utilizar una polea mecánica suspendida a gran altura se empleen varias poleas suspendidas más bajas. Es necesario equipo de mucha fuerza para transferir a popa, en preparación del próximo lance, el extremo de proa de la red. Se está experimentando el empleo de arrastreros con rampa a popa para lanzar y recoger la red por popa. En este caso, ambas alas de la red se halan al mismo tiempo. La captura se salabardea o se iza por la rampa en un copo análogo al de un arte de arrastre. Para mecanizar ulteriormente las operaciones de pesca se propone el empleo de bombas para peces y sistemas para el acarreo del pescado. En vez de aparatos plurivalentes se necesitan maquinillas diseñadas específicamente para la pesca con artes de cerco. El empleo de maquinillas sumergidas para la pesca de cerco parece prometedor para el futuro.

FOR many years, methods and equipment for purse seining changed very little but during the last decade extensive progress has been made by using larger vessels with greater range and better techniques which have resulted in greater vessel and fleet productivity. The utilization of synthetic materials for gear, the introduction of electronic fish finding equipment and mechanized means for handling gear and catches have all contributed to this advancement.

HANDLING PURSE SEINES

Generally, purse seining methods are of two types, one-boat and two-boat, which, according to the method of pursing and hauling, can be divided into three groups: side, stern and bow. The side method is the traditional one used by commercial fleets. The other two are still experimental but of great interest. The classification of purse seining types and methods is shown in fig 1.

At present the side method is well developed and utilized by vessels of different sizes and designs. Widespread use can be explained by the following considerations: shooting a seine is carried out not only from the stern but also from the side and pursing and hauling is from the side. In this case the operations with the lines and netting are performed at different places which extends the operational space and creates favourable conditions for handling and discharging the catch.

However, side seining has the following disadvantages: a vessel is drawn into the seine in the process of pursing and hauling, and it is therefore necessary to have a rather powerful skiff or manoeuvring devices (side thrusters) to counter this. Since the boat-net interaction creates considerable loads while pursing and hauling, the larger the vessel and her sail area, the greater are the loads applied. Setting the seine is carried out in such a way that the vessel will be positioned with her operating side to the wind and owing to this manoeuvre the setting is more difficult. These drawbacks are more significant when using large vessels.

The stern seining method (fig 2) is characterized by the fact that pursing, hauling and emptying the catch are all carried out from the stern—although the latter can be done on the side as well. The advantage of this method is that the sail area of the vessel directed to the wind astern is reduced considerably. This results in smaller loads being applied to the gear. The problem of developing purse seining for pelagic high seas fish will be solved with the application of large, specialized and multipurpose vessels and for this reason stern purse seining is worthy of further development.

However, it is possible to identify now some difficulties which will be faced in its development. Since all the operations are concentrated on the stern, the working space is narrowed, which results in some difficulties in handling the catch. Though it has been pointed out that the vessel can be manoeuvred near the seine and can be maintained in position, the vessel stern cannot be permitted to enter the seine appreciably. The method of hauling the seine bunt and discharging the fish has not been worked out completely; however, experiments show

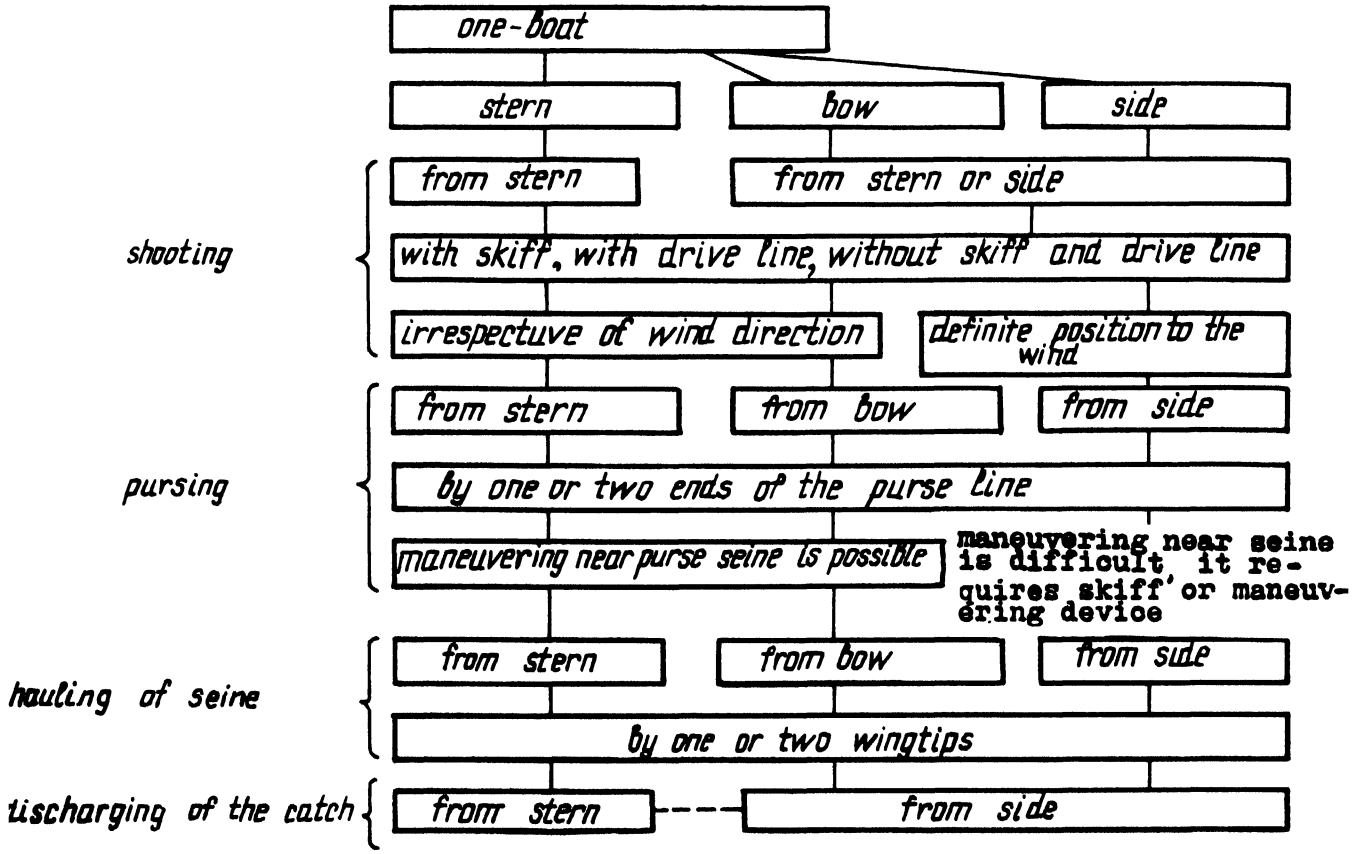


Fig 1. Classification of commercial one-boat purse seining methods

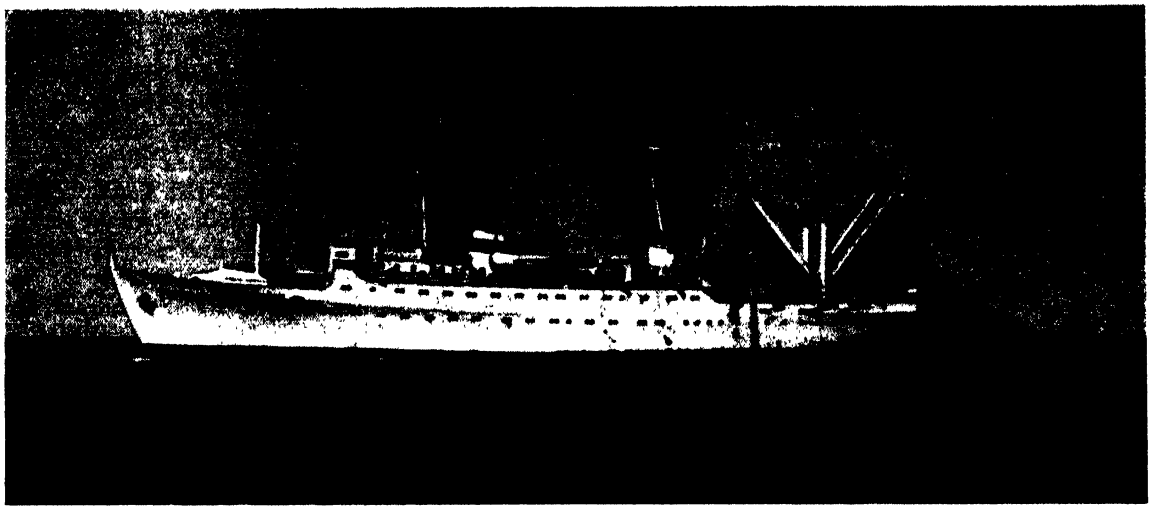


Fig 2. Seine hauling from the stern of a large vessel

that this can be carried out by the same means as in the side method. The most practical method is to dry the bunt with the seine hauling mechanism and to discharge the fish by using a special net bag laced into the seine bunt.

At present the bow purse seining method is the least developed (fig 3). It is characterized by pursing and

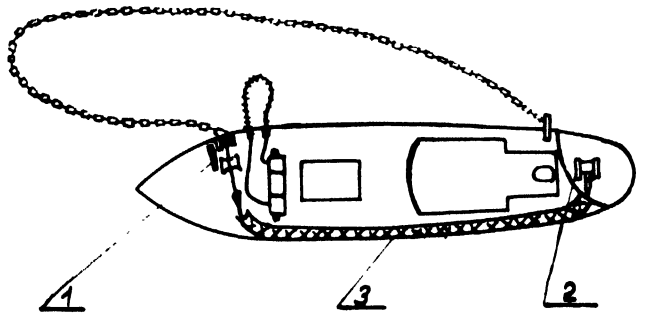


Fig 3. Scheme of seine hauling from the bow (1) powered block (hauling unit), (2) powered block (transport unit), (3) seine

hauling the seine from the vessel's bow. Like the two other methods, the seine setting is performed from the stern. Pursing can be done by one or both ends of the purse line and hauling by one or both wingtips. Since the bow purse seining method hasn't been tested it is possible to only suggest the advantages and disadvantages. One of the advantages is the possibility to manoeuvre the vessel relative to the seine with a minimum hazard of entangling with the propeller. The vessel can freely run away from the seine and move up to it and the loads applied to the gear in pursing and hauling the seine would be at a minimum level. Also, loads are expected to be less because the vessel's sail area in the headwind position is less than with the wind abeam. This method has the disadvantage that, since the seine must be transported from bow to stern, bunts may have to be provided in both ends.

PURSING, HAULING AND STOWING

There are three methods of operating a purse seine: (1) with the aid of a purse boat; (2) with the help of a drive line; and (3) without a purse boat or drive line. With the drive line method there are two additional operations—setting and hauling the drive line. Fishing experts have not yet agreed on the necessity of a special mechanism for this purpose. Some think that it is necessary to have a separate winch or drum mounted on the standard winch for hauling the drive line, and others feel that the drive line should be hauled with the same winch drum on which the purse line is wound. The advantage of the latter is that there is no need to disconnect the drive and purse lines. However, in this case the winch speed range needs to be increased. Despite the fact that pursing by both purse line ends has an obvious advantage, till now the seine is pursed usually by one line end. It accounts for the fact that most of the winches used in purse seining are out of date as concerns their characteristics due to the increased dimensions of modern seines.

The modern trend in the development of gear handling methods points out the expediency of turning from multi-purpose winches to single-purpose ones controlled from a central position. For example, the operation of setting and hauling the drive and purse line can be carried out by two single-purpose winches. One of them provides for paying away and hauling the drive line connected to the purse line and the other for setting and hauling the purse line.

Of great interest is a new method of pursing with winches lowered into the sea to the leadline level. Such a method of pursing is expected to increase the volume of water strained and decrease to a considerable extent the loads applied to the winch and seine. Too little data is available yet to draw conclusions as regards this method of pursing. It is only possible to point out that it is of interest but, if it is found to be feasible, it will result in basic changes in fishing methods and equipment.

Hauling and stowing the seine remain the most difficult and labour consuming operations. Let us

consider the problems of mechanization of hauling and stowing purse seines in more detail. At present the mechanical devices for these purposes are distinguished by a variety in use. The seine hauling devices may be divided into three classes: friction, winding and gripping (fig 4). The friction mechanisms are the most common at present. This class in turn can be divided into two groups—the mechanisms in which the operating units (friction drums) have a wedging profile and the mechanisms in which the friction drums have a non-wedging profile. The first group includes the mechanisms of the Far East type and Norwegian mechanisms of Types X-2A and X-2C. The second group includes the mechanisms designed by S. S. Ostapenko and V. M. Kirillov (USSR). Both groups have single, double and multi-drum mechanisms.

The winding class is represented by drum type reels which may be arranged horizontally, vertically or swivelling.

The gripping class may be divided into two groups: the mechanisms with the operating bodies in which netting is self-gripped and mechanisms with operating units which grip the netting by force. These subgroups in turn may also include conventionally separated mechanisms with the operating bodies locally gripping the netting and integrally (comparatively large section) gripping the netting.

Different becket units (mechanisms designed by VNIRO and SakhTINRO, NIKIMRP, etc) may serve as examples of the self-gripping unit of the local gripping type; the mechanisms of the same group but of integral gripping are represented by a French seine hauling mechanism and a unit with pneumatic drums (Japan). An example of local forced gripping are drums with netting cam grips. Gripping the netting between two drums or drum's sides is an example of integral gripping.

The suggested classification sub-divides the seine hauling mechanisms mainly according to the way in which the operating bodies handle and contact the netting. Some existing mechanisms do not fit in this scheme and may be attributed at the same time to two classes of sub-groups. Nevertheless, this classification gives an indication of the possibilities available to solve a given problem of designing a hauling mechanism with pre-set characteristics.

The hauling devices for purse seines can also be classified according to their arrangement aboard the ship into deck and overhead mounted equipment. This aspect is of significance insofar as the weight of the seine may be used as an active force for hauling (overhead method). The deck mechanisms are units mounted on a deck, a seine deck or a platform, while the overhead ones are suspended from a derrick, davit, mast or special framework. Until the mid-fifties the deck mounted units were mainly used. It should be pointed out that at the time the deck hauling units were most developed in the USSR. All the seiners were equipped with two-drum friction hauling mechanisms.

Beginning in the mid-fifties and especially in the late fifties, the overhead seine hauling units (power block) found a wide application and, as a result, purse seining efficiency increased. The experience obtained in using the overhead power blocks has shown that they provide for a high level of mechanization of the purse seine hauling operation. Since these power blocks have a higher traction force this permitted an increase in the purse seine size which in turn resulted in raising the tractive force. The use of overhead power blocks with higher tractive force created stability problems which restricted the application. Additional ballast to provide the required

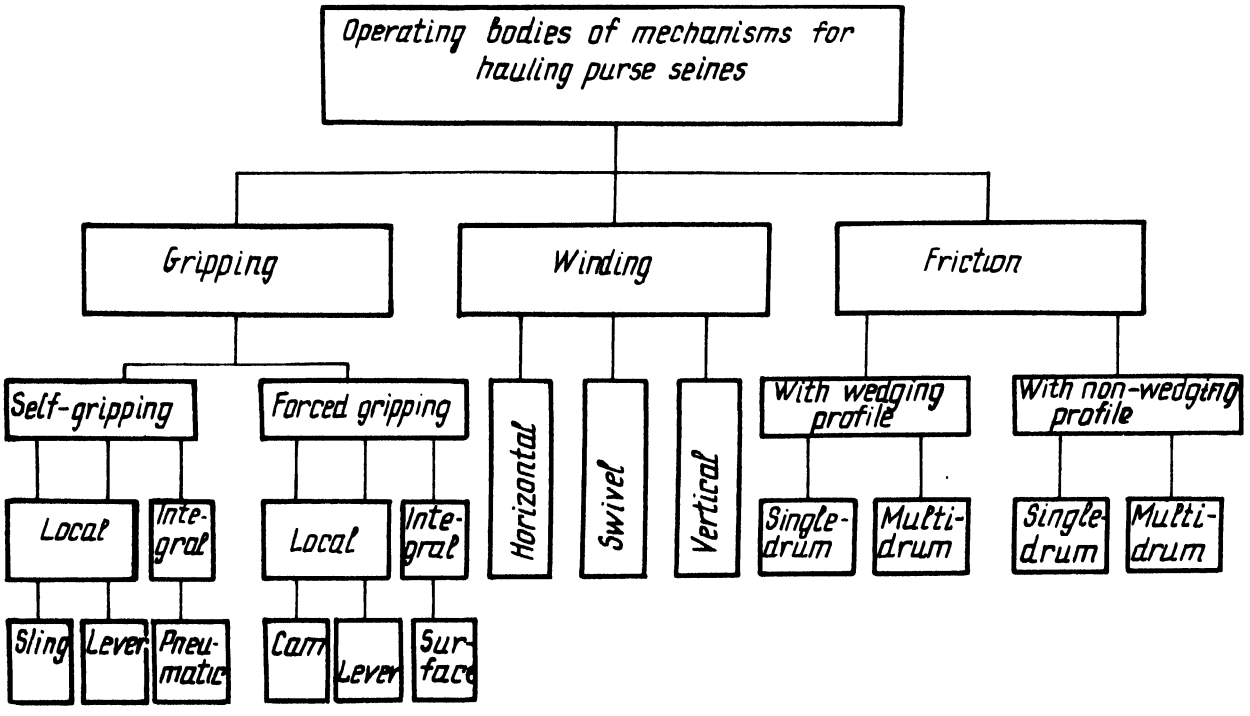


Fig 4. Classification of principles and devices for mechanical hauling of purse seines

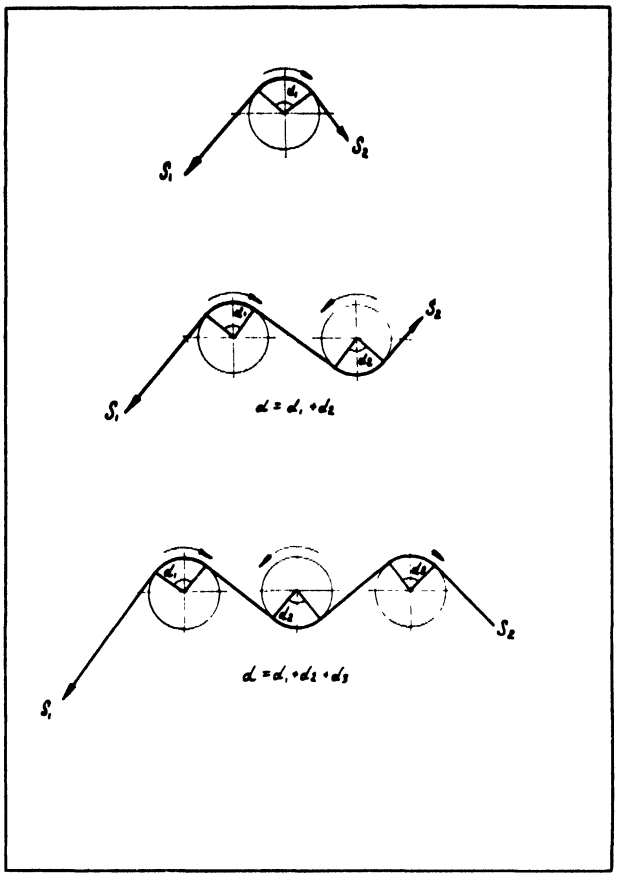


Fig 5. Diagrams for calculating performance of powered blocks

stability naturally decreases the vessel's useful load capacity. The increase of the power block tractive force enabled the hauling of larger purse seines which raised the problem of mechanization for transporting the large purse seine from the hauling site to the stowing place.

A new tendency in mechanization is towards "power systems" with a considerable tractive force for hauling the seine and provisions for transporting it from the hauling point to the stowing area. They consist of a hauling unit and transporting unit which is usually a single drum overhead mechanism. For hauling, use may be made of single drum overhead (MBK-5 and MBK-7, USSR) or single drum deck units ("Abas", Norway), two drum deck (X-2C, Norway), three drum deck ("Triplex", Norway) and four drum deck units (USSR).

The interaction of the seine netting with the powered drum may be considered similar, with certain assumptions, to the interaction of an imponderable and inelastic thread with a drum. For this case (fig 5) Euler's equation is used:

$$S_1 = S_2 e^{\mu\alpha} \quad (1)$$

where: S_1 = tension on the incoming part of the seine

S_2 = tension on the outgoing part of the seine

e = base of natural logarithms

μ = actual friction coefficient of seine and drum surface which is determined experimentally

α = contact angle of seine and drum

When the seine netting has contact with more than one drum (fig 5) equation (1) assumes the form:

$$S_1 = S_2 e^{\mu(\alpha_1+\alpha_2\ldots)} = S_2 e^{\mu\Sigma\alpha} \quad (2)$$

The more the number of drums the larger the force which can be developed by the hauling unit.

Usually the force S_2 is the sum of several forces, e.g.

$$S_2 = Pn+q \quad (3)$$

P = mean force developed by one fisherman in hauling a purse seine

n = number of participating fishermen

q = weight of a running meter of seine

H = distance of the drum axis to the deck

Theoretically, two extreme cases of S_2 could occur. The first is when distance H from the drum axis to the deck equals 0.

$$H = 0; \text{ then } qH = 0; S_2 = Pn. \quad (4)$$

The second case occurs when the product of qH is rather great and equal to pre-set value for S_2. In this case equation (2) becomes:

$$S_2 = qH. \quad (5)$$

The reason for the overhead power block arrangement is to use the weight of the part of the seine which has passed the block as an active force for saving manual labour.

Since one would naturally not want to increase the weight of the seine the force S_2 can be increased only by increasing the height of the power block suspension which consequently has reached 14 to 15 m on some seiners. There is, however, a limit for the suspension height of power blocks with regard to vessel stability and it is therefore preferable to replace the weight qH by increased friction using additional drums (fig 6). Such a combination of seine hauling units may be called a power complex. Power complexes have been acquiring an ever increasing significance recently.

Let us consider the operating method of the power blocks with their individual drives and reveal the basic data for their calculation (fig 6a). The first power block drum has contact angle α_1, the incoming component tension S_1, and the outgoing component tension S_{np}. The drum of the second power block has contact angle α_2, force of the incoming component S_{np} and that of the running down S_2. Drum III is rotating free and serves as a guide unit. Friction losses of this drum are neglible.

For these conditions the relationships are:

$$\frac{S_1}{S_{np}} = e^{\mu\alpha_1} \quad (6) \qquad \frac{S_{np}}{S_2} = e^{\mu\alpha_2} \quad (7)$$

Comparing these we find there is no need for high installation of the first power block since force S_{np} of the netting coming off the first power block is provided by the second one. As S_2 is less than S_{np} the operation of the second power block requires only a small qH value, and therefore the second power unit can be suspended at a comparatively low height. Each power unit has the following force transferred:

$$P_1 = S_1 - S_{np} \quad (8)$$

$$P_2 = S_{np} - S_2 \quad (9)$$

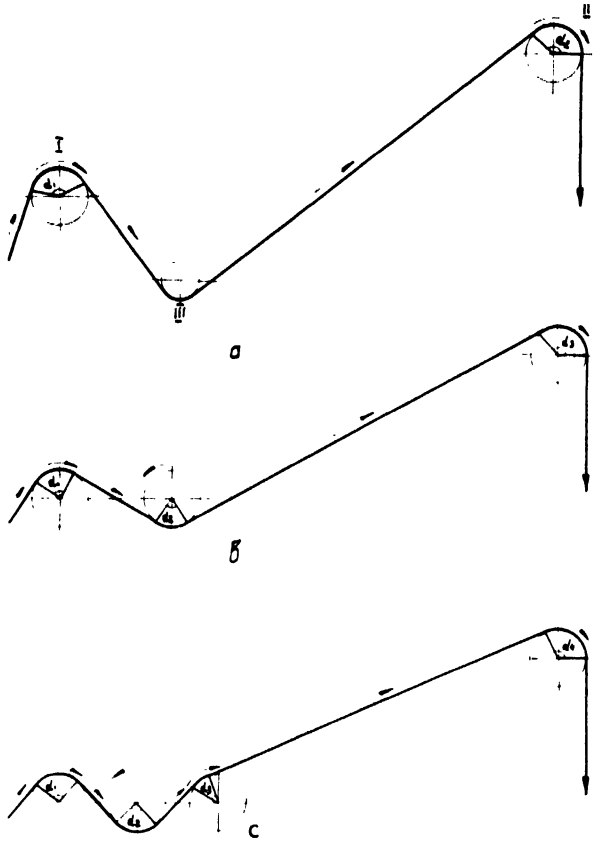


Fig 6. Diagrams of seine hauling power complexes. (a) two overhead blocks with guide roller, (b) two-drum deck unit with one overhead block, (c) three-drum deck unit with one overhead block

The capacity of each power unit will be:

$$N_1 = \frac{P_1 . V_1}{102 . \eta_1} \text{ (kW)}, \quad (10)$$

$$N_2 = \frac{P_2 . V_2}{102 . \eta_2} \text{ (kW)}, \quad (11)$$

where: N_1, N_2 = capacities of the first and second power units respectively

V_1, V_2 = hauling speeds of the first and second units

η_1, η_2 = efficiencies of the units

It is possible to set quite definite operating conditions of the power blocks, for example, a case where the capacities of both units are required to be equal, i.e. $N_1 = N_2$. It is true if

$$\frac{P_1 . V_2}{102 . \eta_1} = \frac{P_2 . V_2}{102 . \eta_2} \quad (12)$$

Since $V_1 = V_2 = V$ and $\eta_1 = \eta_2$ it should be provided for $P_1 = P_2$. This is possible if

$$S_1 - S_{np} = S_{np} - S_2, \quad (13)$$

i.e. when both drums have equal friction forces $F_1 = F_2$. From equation (13) we can determine the value of an intermediate force

$$2S_{np} = S_1 + S_2,$$

and therefore

$$S_{np} = \frac{S_1 + S_2}{2}$$

Equations (6) and (7) may be written as

$$\ln \frac{S_1}{S_{np}} = \mu\alpha_1; \quad \ln \frac{S_{np}}{S_2} = \mu\alpha_2$$

Assuming that the friction coefficients of both drums are equal we obtain:

$$\frac{\ln S_1 - \ln S_{np}}{\ln S_{np} - \ln S_2} = \frac{\alpha_1}{\alpha_2}.$$

If the friction coefficients are different, then

$$\frac{\ln S_1 - \ln S_{np}}{\ln S_{np} - \ln S_2} = \frac{\mu_1 . \alpha_1}{\mu_2 . \alpha_2}$$

Hence, knowing S_1 and S_2 it is possible to determine the contact angles of the netting and drums and design operation conditions of the power blocks under which their tractive forces will be equal and the capacities of the drives are similar. Using these formulae we can calculate the capacity and traction characteristics of the power units so that the tractive force and capacity of the second power (stowing) block would be minimized.

Another possible case is of some interest when the hauling speeds of the power blocks are not equal. The first case is when the hauling speed of the first unit exceeds that of the second one, i.e. $V_1 > V_2$, and the second case when the hauling speed of the first unit is less than that of the second one, i.e. $V_1 < V_2$. In the first case $S_{np} = qH$, i.e. the force applied to the outgoing component after the first power block is equal to its weight. The second unit takes the seine from the deck of the vessel and its tractive force is small in this example, as compared with the tractive effort of the first one. Both power units operate not as a single hauling system but independent of each other; the second unit does not increase the tractive force of the first power block. In practice, such a design may be used only when it is necessary to re-stow the seine on the vessel. The second case is more complicated. Sometimes, in order to prevent netting being driven into the non-operating sector of the first block, the hauling rate of the second unit is speeded up. The following occurs in this case. With an increase of the handling speed, V_2 rises within the range of the second unit's traction ability. The tension of the netting of the intermediate branch is S'_{np} which reaches value $S'_{np} > S_{np}$. If the external load (S_1) remains constant, the transferred circumferential force of the first block decreases, i.e. $P' < P$ since $S_1 - S'_{np}$. Due to this, a decrease is also observed in the torque and capacity required to perform the hauling operation. The circumferential force of the second unit increases up to a value $P' = S'_{np} - S_2$ and as a result the torque and required capacity increase as well. Thus, the increased hauling speed of the second power unit results in re-distributing the tractive force between the power units.

One of the most essential factors in hauling a seine is to reduce the time required for the operation. Modern means of mechanization permit an increase of the hauling speed. However, a limiting factor is the stowing speed, which usually does not exceed 12 to 15 m/min because

mechanical means of stowing a seine have not yet been developed. One way to speed this operation is to haul both seine wings simultaneously. Irrespective of the good results of experiments with this method it has not found wide application. In addition to the increase of hauling speed, such a method has a number of other advantages. By controlling the speed of hauling the wings it is possible to keep the vessel in the most favourable position relative to the seine and the whole crew takes part in the operation of drying the catch and discharging the fish. This is the most labour consuming operation, especially on large vessels. Japanese fishermen use power rollers for this purpose which facilitates the operation, but the problem of mechanization of the drying-up operation requires further investigation.

In recent years, submersible fish pumps, characterized by a high output and simple operation, have found wide application. Further improvement of fish pumps should be directed towards increasing the head and decreasing fish damage in the pump.

As a result of the foregoing it is possible to draw the following conclusions:

1. At present the side fishing purse seine method is widely used. It is necessary to improve it on the basis of existing experience in the following directions:
   (a) Making the operation independent of seine skiffs and helper boats
   (b) Development of single-purpose winches with increased traction and speed characteristics to permit pursing from both ends
   (c) Introduction of power blocks and power complexes for hauling seines by both wings simultaneously
   (d) Development of mechanized means for stowing seines
   (e) Development of mechanized means for drying the catch
   (f) Improvement of the design and wider use of submersible pumps for discharging fish from the seines
   (g) Equipping vessels with manoeuvring devices (side thrusters) to facilitate vessel manoeuvring near the seine
2. Since stern seining offers promise, especially for large multi-purpose vessels with stern ramps, it is expedient to:
   (a) Continue experiments on methods of shooting, pursing and hauling the seine
   (b) Carry out investigations and development of different methods of drying and emptying the seine
3. The bow purse seining method is undoubtedly of great interest. It is necessary to conduct similar experiments with a view to determining its advantages as compared with the side and stern methods.

Combination Fishing Vessels

G. E. Kristinsson

Navires de pêche polyvalents

Les navires susceptibles d'être convertis facilement à plusieurs types d'engins de pêche connaissent une vogue croissante au Canada. Bien qu'il soit peu probable que l'on puisse concevoir un seul navire capable de pêcher d'une manière efficace avec tous les types d'engins, certaines combinaisons se sont déjà révélées profitables par l'expérience commerciale ou présentent de belles perspectives pour l'avenir. On peut citet comme examples:

(a) Chalutier de fond—seineur
(b) Chalutier de fond et pélagique—seineur
(c) Chalutier de fond—palangrier
(d) Chalutier de fond—caseyeur (crabe)
(e) Chalutier crevettier—caseyeur (crabe)
(f) Bateau de pêche aux filets maillants—caseyeur (homard).

L'économie des pêches commerciales donne actuellement une impulsion considérable à la construction de petits navires polyvalents (24–46 m). Selon toute probabilité, l'enrouleur de filet rendra plus pratique l'emploi de plusieurs engins. La conception des navires polyvalents nécessite la prise en considération de données telles que: espèces recherchées, secteurs pêchés, conditions météorologiques et hydrologiques, facilités portuaires, opérations projetées et économie de pêches, disponibilité supposée du poisson, besoins pour le confort de l'équipage et aisance des membres de l'équipage dans la convertibilité. En 1964–65, le navire *Green Waters* (voir schéma dans le texte) a participé avec succès à la pêche à la seine coulissante du thon et du hareng, et au chalutage de fond au cours de la même saison.

Pesqueros mixtos

Adquieren popularidad en Canadá los barcos que pueden emplear diversas clases de equipo de pesca. Aunque no es probable que un solo barco pueda proyecto arse para trabajar eficasmente toda clase de artes de pesca, hay ciertas combinaciones que han resultado ser rentables comercialmente o que tienen buenas posibilidades de serlo en el futuro. Entre los ejemplos están:

(a) Arrastrero para pescar en el fondo—cerquero
(b) Arrastero para pescar en el fondo y entre dos aguas—cerquero
(c) Arrastrero para pescar en el fondo—palangrero
(d) Arrastrero para pescar en el fondo—cangrejero (nasas)
(e) Arrastrero camaronero—cangrejero (nasas)
(f) Barco para la pesca con redes de enmalle—langostero (nasas)

La economía de la pesca comercial canadiense da enorme impulso a la construcción de pesqueros mixtos pequeños (de 80 a 150 pies de eslora). Es muy probable que el carretel de la red haga más práctico el empleo de diversas clases de equipo. El proyecto de pesqueros mixtos requiere que se tengra en consideración determinados datos, como son: especies que se propone pescar, lugares en los que se va a pescar, condiciones meteorólogicas a hidrográficas, instalaciones portuarias, operaciones previstas y aspectos económicos de la pesca, disponibilidad prevista de pescado, comodidad de la tripulación y facilidad de adaptación del barco por la propia tripulación. En 1964–65 el pesquero *Green Waters* (ilustración incluída en el texto) practicó con éxito en una sola campaña la pesca del atún y del arenque con redes de cerco y la de arrastre en el fondo.

DESIGN parameters and operation requirements have to be combined in development and operation of combination fishing vessels. When sufficient information is available from existing vessels their combined technical and economic appraisal will help to develop the vessels type, size, speed, displacement, engine fuel and fish carrying capacities in order to obtain the maximum expectation of profitability.

Combination fishing vessels (e.g. fig 1) could be classified into several categories including the following:

(a) Combination stern bottom trawler and purse seiner
(b) Combination stern bottom, midwater trawler and purse seiner
(c) Combination longliner and dragger
(d) Combination crab fishing vessels and dragger
(e) Combination longliner, scalloper, crab fishing vessels and shrimp trawler
(f) Combination lobster boat and gillnetter

It would be much too extensive to deal here with all the various fishing methods or their requirements. Therefore, only those most commonly used in bulk fishing ventures are dealt with, such as:

(i) Bottom trawling
(ii) Midwater trawling
(iii) Purse seining (power block and drum)
(iv) Longlining

GENERAL DESIGN FACTORS

Although it would be unwise to generalize from the economic and technical data of any one country to any other, certain conclusions have shown themselves sufficiently important to warrant detailed study by those concerned with general fishing vessel development. It would seem logical to design all fishing vessels on the long-term expectation that fish catching rates will tend to decrease on traditional fishing grounds, despite attempts being made to conserve stocks. By taking this more conservative view of fish availability, the tendency might be towards a slightly smaller vessel in any situation, utilizing its full fishhold capacity for a greater number of voyages early in its life. The situation sometimes arises when fishing has to be curtailed due to lack of stowage space on board, but there should be economic gain later in the life of such a vessel, when the percentage of fish carried in terms of hold capacity will be higher for the smaller less costly vessel. If, however, fish preservation methods improve and, for example, freezing plants can be fitted to existing vessels, thereby increasing time on fishing grounds, the smaller vessel will show a quicker restoration to its designed catching rate compared with the larger vessel. Of course, in this context it should always be borne in mind that there is a minimum length of vessel which will be acceptable for wind and sea conditions pertaining in the areas being fished.

For fishing vessels around 80 to 150 ft BP length, there is still a tendency to be unaware of the benefits to be gained by increasing both beam and draft above average practice in many countries. This has associated advantages in providing safe stability characteristics and reducing wetness, by providing increased overhang with increased rake of stem profile.

Part of the design procedures include assessment of stability requirements for various freeboards, changes in loading conditions from design values, and the effect on stability by changes in hull form.

An important anti-rolling device, particularly suited to medium and large size fishing vessels, is the passive stabilizer tank which transfers liquid from one side of the ship to other in antiphase with its motion. A typical passive stabilizer, for example, consists of twin water tanks interconnected by a channel or flume made to special design for a particular vessel, and gives approximately 65 per cent roll reduction, independent of ship speed. Devices of this type perform a very useful function in increasing crew comfort and improving earning capacity in rough weather.

OPERATING FACTORS AFFECTING DESIGN

To make assessments of vessel characteristics it is necessary to have available the following data categories and sub-divisions.

Operational information must include quantitative assessments of the effects of different types of fishing gear, predicted average catching rates likely to be obtained at each fishing ground, assessment of skipper ability and the effects on catching rate of vessel size.

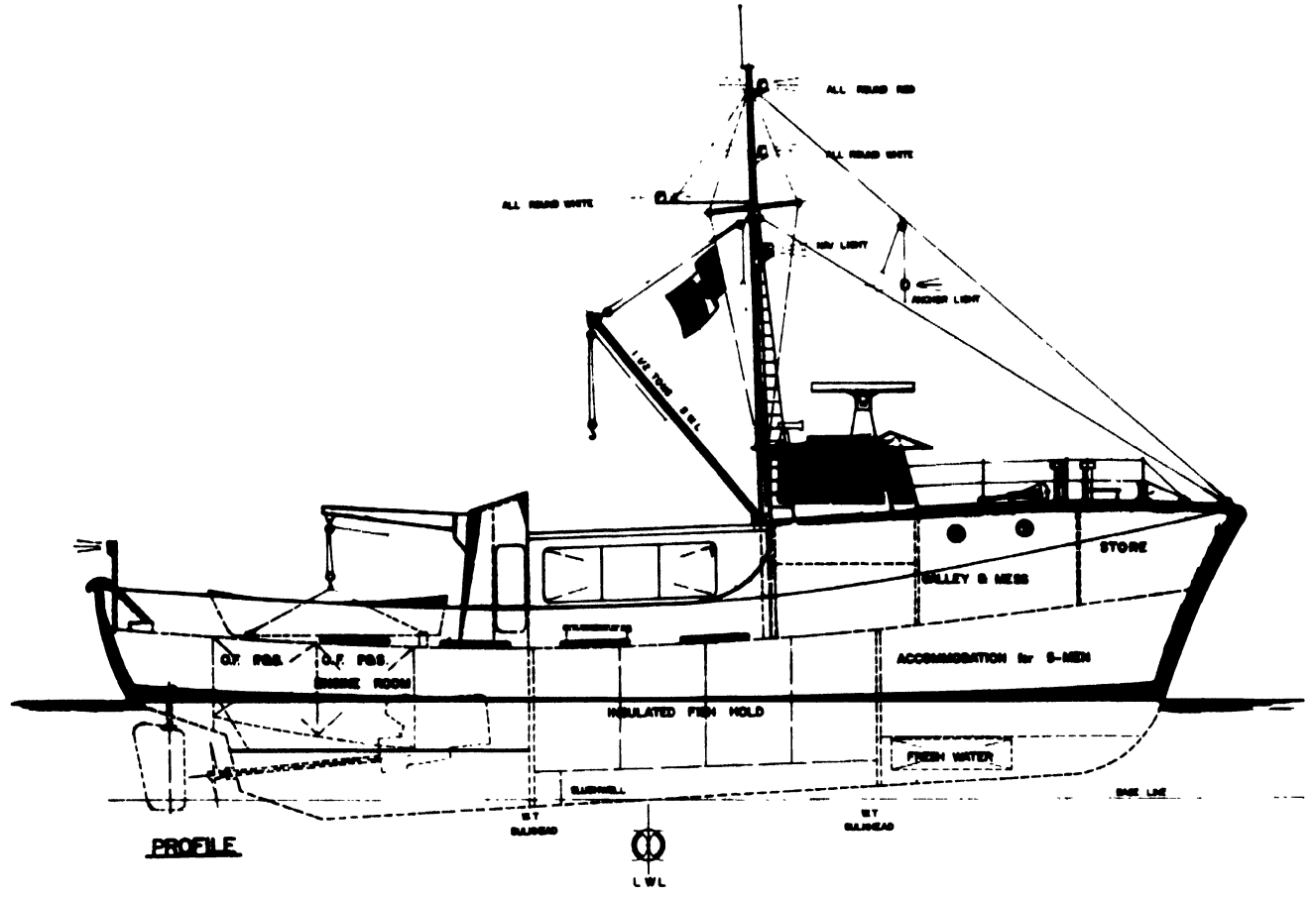
Operational data which are normally kept by the vessel owner and which must be allowed for in the design study, include both running and replacement costs of equipment and a breakdown of voyage expenses. These will include skipper's and crew's wages, oil, fuel, ice, provisions, stores, fishing gear, radio and radar expenses, dock charges, marine and crew's cooperation insurance, together with management and establishment overheads. By careful study of such items for existing vessels it is possible to express them in terms of catching rate, fishing time, specific fuel consumption and similar factors which can determine realistic estimates of expense for new vessels.

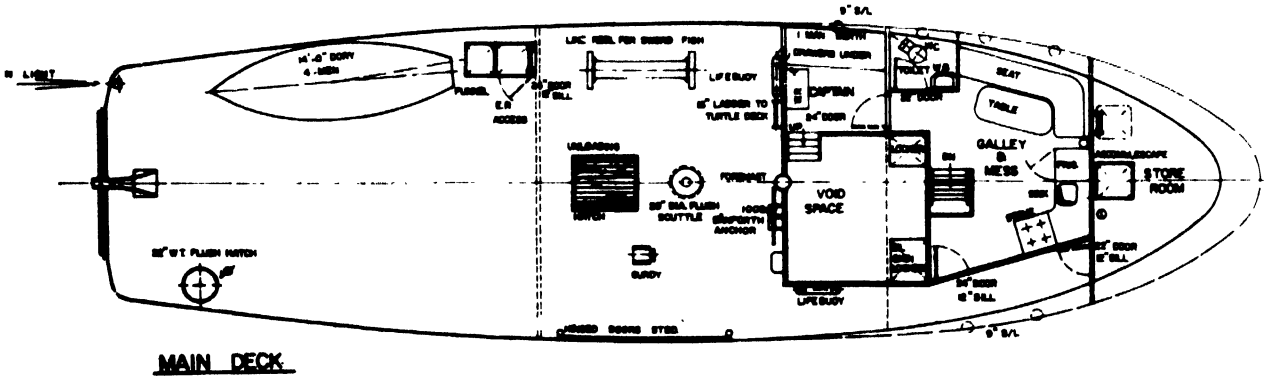
The ports of landing and departure have to be considered in relation to the sizes of the vessel and draft limitation, loading and unloading facilities and the corresponding costs.

The most important factor is the price likely to be realized for the fish and its by-products. Fish prices may vary considerably between ports in some countries and this may influence the vessel size. Shore processing and storage facilities have an interaction with vessel size and composition of the fleet and matching fish supplies with the shore processing plant requires careful planning.

Meteorological data

By analysing effective fishing times spent on various grounds over a considerable period, allowing for lost time due to bad weather in relation to total voyage time, it is found that some fishing grounds give consistently higher or lower ratios of effectiveness. When there is a choice of access to several fishing grounds vessels must be designed and routed with such facts in mind, since fish catching rate in these circumstances is not the sole criterion.


ALL ROUND RED
ALL ROUND WHITE
ALL ROUND WHITE
MW LIGHT
ANCHOR LIGHT
STORE
GALLEY & MESS
ACCOMMODATION for 5-MEN
INSULATED FISH HOLD
FRESH WATER
PROFILE
LWL


LIFE BUOY
CAPTAIN
VOID SPACE
GALLEY & MESS
STORE ROOM
MAIN DECK

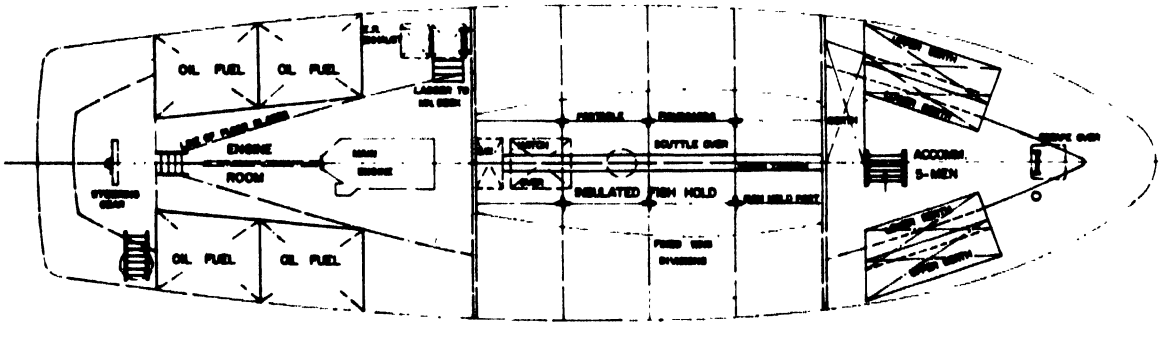

OIL FUEL
OIL FUEL
ENGINE ROOM
OIL FUEL
OIL FUEL
INSULATED FISH HOLD
ACCOMM. 5-MEN
ENGINE, ROOM, FISH HOLD AND FLATS

Fig 1a.

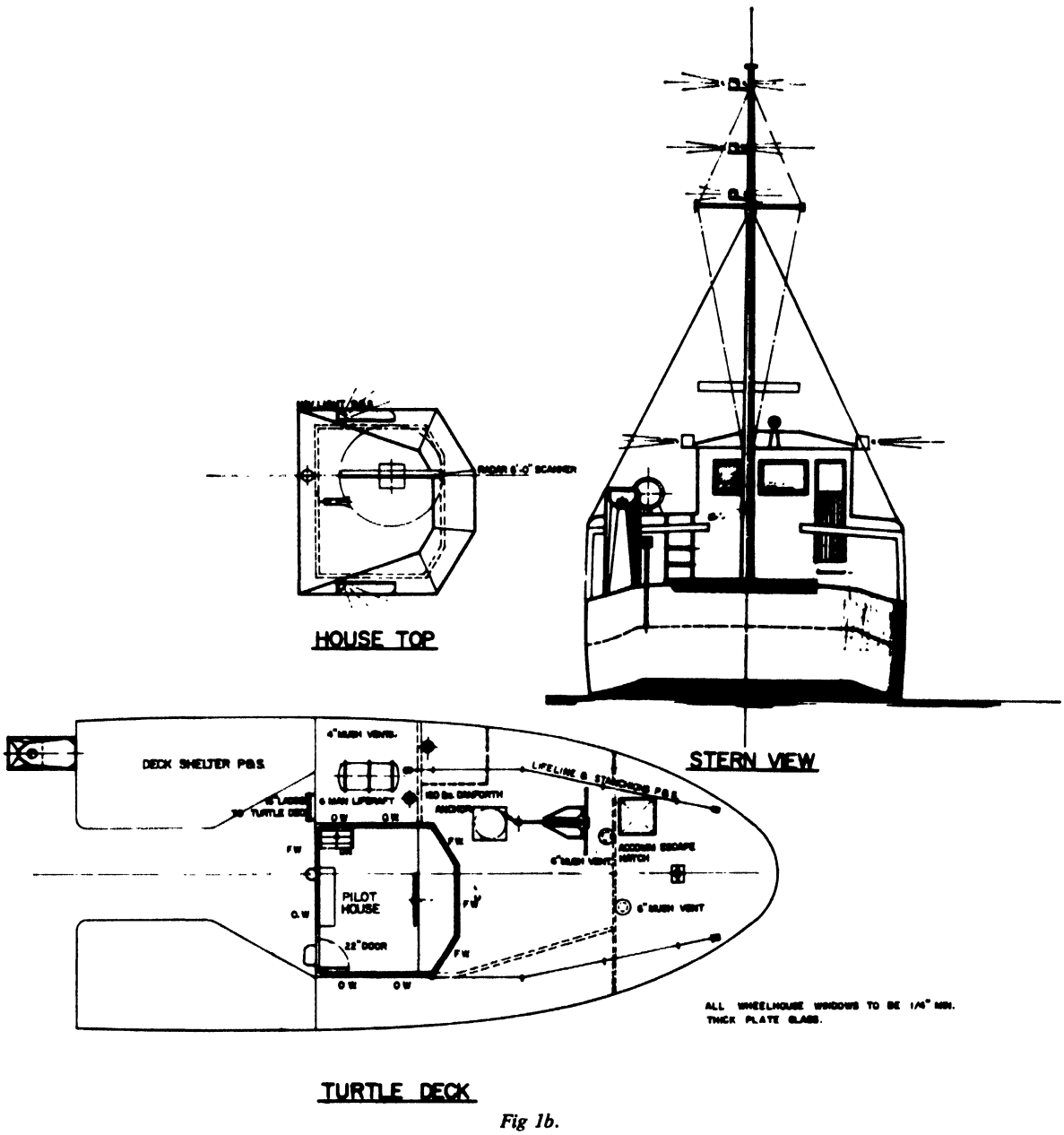


Fig 1b.

Fig 1a (opposite) and Fig 1b. Proposed combination fishing vessel, 66 ft oa, 400 hp, which could be built in steel, wood, fibreglass or ferrocement. Uses include long-lining, dragging, crabbing and shrimping

Hydrodynamic data

Studies have been conducted to establish the effects on overall efficiency of various propulsive devices, including fixed and rotatable nozzle rudders, conventional rudder with varying thickness ratios, and varying hull shape characteristics and their effects on power, and seakeeping qualities, including ship motions. Of particular importance also is the effect of above-water shape at the ends of these vessels and the accelerations which can be tolerated by the crew to avoid excessive fatigue, with consequent loss in operational efficiency.

Marine engineering data

The fuel consumption characteristics of diesel engines are well known so the desirability of running the power unit at more than idling speed will be appreciated. Using controllable pitch propellers allows this to be done whether one or two main engines are being used to drive the ship, and in addition allows the installed power to be developed to its maximum when fishing, when returning from the fishing grounds in loaded condition, and when running light. In a trawler, as in a tug, the variation between free-running speed and working speeds is so great that a fixed pitch propeller designed to a compromise condition would not function efficiently at either speed. Perhaps the most important consideration from the point of view of the ship's master is that a c.p. propeller lends itself to direct bridge control, with all attendant benefits.

Side thrusters are becoming commonly used on combination vessels, especially on purse seiners and these

should be given close consideration when planning a new type combination vessel.

Selection of deck machinery and fish finding gear is important, and this can only be accomplished effectively by obtaining expert advice from gear technologists and experienced captains. This of course refers to system adaptations, as several pieces of equipment are available providing equal operation efficiency.

Shipbuilder's data

It is necessary to have a detailed cost breakdown of comparable existing vessels, together with all manufacturers' supply items in order to predict capital costs for any new construction. When making radical departures in either dimensions or equipment, it is necessary to perform systematic cost evaluations to secure realistic estimates. This data is derived from shipyards over a stated period with due allowance for increased costs.

GENERAL OPERATION FACTORS

Combination vessels are becoming more and more popular. Fishermen request that the vessels be so equipped that conversion from one fishing method to the other can be done by themselves, and not require costly shipyards or repairing yards.

The most preferred arrangement is to have two or three different types of gear on board, all ready for shooting at a time decided by the fishing master. By adopting drum gear handling arrangements, this can easily be accomplished.

The author has recently been working on an arrangement where the vessel has actually four sets of gears on drums and no conversion is necessary to change over from one operation to the other, namely:

(a) Tow bottom trawls each on separate drums
(b) Midwater trawl on a drum
(c) Purse seine on a drum

Two bottom trawls are arranged to counteract risk of damage. The second trawl can be used immediately in case the other requires repairs.

Drum purse seining is now more or less replacing power block seining in British Columbia. In most cases the power block now only serves to off-load purse seines for repairs or when changing to another method of fishing.

It is claimed that drum purse seining reduces the crew further from eight to five on typical 50 to 70 ft salmon and herring seiners as compared with power block operation.

Practical Success

Perhaps the best way to illustrate some operation factors of a combination vessel would be to tell of some outstanding fishermen who have shown steady growth. The brothers, Medford and Burris Mathews, and Captain Stanley Savage of Campobello Island, N.B., Canada, first started purse seining in sardine weirs in 1934, using dories and a cotton seine.

During the same year, they began the first offshore herring purse seining with their father in the Bay of Fundy region operating a cotton seine out of 15 ft oar-powered dories. During the years they had continuous success by adopting new boats and improved fishing methods.

In 1963 the Mathews and Savage brothers took a giant step forward and built the first truly combination fishing vessels on Canada's Atlantic coast. These were the 92 ft steel sister ships *Blue Waters* (fig 2) owned by Mathew brothers, and *Green Waters* owned by Savage brothers, which are capable of the following fishing operations:

(a) Bottom trawling (both over the side and stern)
(b) Midwater trawling
(c) Herring purse seining
(d) Tuna purse seining
(e) Longlining

They not only successfully pioneered the first tuna purse seining venture out of eastern Canada, but were also successful in herring seining and trawling.

These were the first vessels to be equipped with brine spray refrigeration and two water jet side thrusters. The vessels are radical in design having the galley and sleeping quarters located separately on the main deck under a raised focsle head, while the engine room is located aft and a ferry boat type bridge straddles the deck amidships.

Captain Savage confirms that in 1964/65 the *Green Waters* completed an operation cycle using the three combinations of gear and all were successful.

(i) Tuna seining, May to September 1964
(ii) Herring seining, September to December 1964
(iii) Bottom trawling, December 1964 to May 1965

To further demonstrate the success of these boats, Captain Medford Mathews has reported that the *Blue Waters* in 1966/67 caught 18,000 T of herring in an eleven month period. *Blue Waters* and *Green Waters* are equipped with powered side rollers fitted to the bulwarks to assist in drying up the bunt when purse seining. Similar rollers have been used on smaller wooden seiners of the Bay of Fundy region for some time and were introduced about 1955 by Mr. Stanley Savage.

The general particulars of the *Green Waters* and *Blue Waters* combination purse seiner sterntrawler and side trawler are:

Length overall	91 ft 10 in
Length between perpendiculars	80 ft
Breadth moulded	22 ft
Depth moulded	12 ft
Draft mean (moulded)	8 ft 10 in
Main engine	G.M. 2 cycles, tandem twin 24 cylinder in "V" Series 71 Max. BHP 1,008 at 2,300 rpm. Net continuous SHP 665 at 1,800 rpm.
Fuel oil	6,000 gal imp.
Speed (max)	12 kn
Operating range	2,000 nautical miles
Fish hold capacity	150 T of frozen tuna

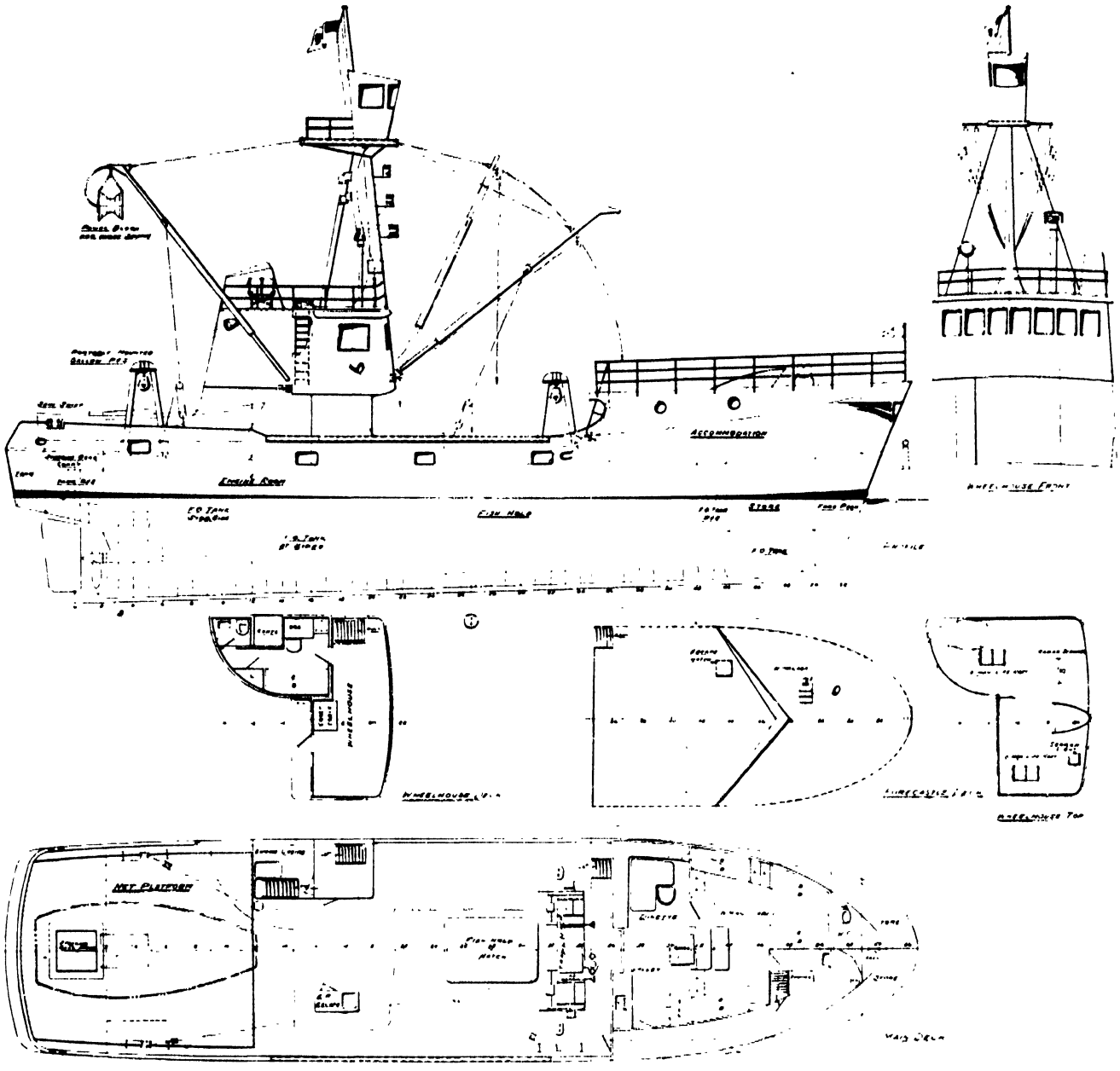


Fig 2. Combination purse seiner/trawlers. Blue Waters *and* Green Waters

The main items of fishing and electronic equipment are:

1 Puretic power block (hydraulic)
1 Three drum trawl winch (Norwinch hydraulic)
2 Hanley water jet nozzles of 1,000 lb thrust each
1 Aluminium purse seine skiff 22 ft o.a.; 140 hp
1 Fishfinder echo sounder, 0 to 600 fm
1 Normal echo sounder, 0 to 200 fm
1 Minneapolis Honeywell sea scanner
1 Loran receiver
1 Marine radar
1 60 W radio telephone
1 Decca navigator
1 Automatic direction finder
1 Gyroscope steering automatic pilot
1 Electric hydraulic steering system with two push buttons and one hand operated remote control

CONCLUDING REMARKS

There is no doubt that many combination vessels built in the past have proved worthwhile ventures, setting the basic pattern for future developments. Fishermen are well aware of the risk involved in building a vessel suitable for one type of operation only.

The author believes that midwater trawling will continue to develop and will become an important method of fishing in various parts of the world. Its appeal lies in its mobility and manoeuvrability. It can be aimed at and towed through a school of fish over bad bottom both in shallow or deep water and operated in worse weather than purse seining. It can fish for small amounts and for scattered fish when it would not be worth setting a purse seine.

Because the midwater trawl is lower in cost and not

susceptible to as much damage, more calculated risks can be taken in fishing it near bad bottom than with a purse seine. The purse seiner, of course, has the advantage in fishing confined inland waters and has up to now enjoyed the ability to produce large quantities in a short period of time. Midwater trawls have, however, as much advantage, if not more, in open waters and have also demonstrated the ability to produce large quantities on a daily basis. This is likely to become more apparent as catching efficiency of the gear improves.

As for Canada in the future, herring will also be of greater value to fishermen when sold for human consumption. A fairly increasing amount of Newfoundland purse seine herring is being filleted and cured for the American market.

It may be interesting to note that most vessels built in Canada today are capable of both purse seining and midwater trawling with quick change from one method to the other right on the grounds as the occasion demands. If such ventures prove profitable more vessels of this type will probably be built. However, owners of such types are likely only to be interested in fishing pelagic species and rarely, if ever, will be interested in groundfish.

On the other hand future owners of stern trawlers who fish primarily groundfish may incorporate features to allow conversion to purse seining, or more probably will build midwater/bottom trawlers capable of catching both groundfish and pelagic species in a single voyage. This is facilitated by the reasonable cost of midwater trawl gear.

The efficiency of purse seining is likely to improve considerably and many more purse seiners will be built in the future and some species may never be caught in any quantity with any other method. However, the boat most likely to be a long time revenue provider will be the vessel with versatile gear handling layout and powerful enough to handle bottom and midwater trawls to the best advantage.

DISCUSSION

DECK EQUIPMENT FOR PURSE SEINING; VESSEL NOISE; FUTURE TRENDS

Thorsteinsson (Iceland) Rapporteur: Many attempts have been made to make purse seining more economical by reduction of crew through the use of mechanical devices. **Hester** discusses the possibility of reducing crew from nine or ten to only four by using a drum for hauling and storing the net. This method is of great interest, but many problems have to be solved before it can be put into use in many fisheries. The main problem associated with reducing crew numbers concerns the stowing of the net. Not only does this operation require many crewmen, but it is also to a great extent responsible for the relatively slow speed of the whole fishing cycle. **Torban's** description of hauling both wings simultaneously also requires a large crew and is therefore only an improvement if the crew must be large to handle the fish. Another shortcoming of this method is the necessity of overhauling one half of the net before reshooting. Perhaps someone from the USSR will comment on this.

Bardarson describes an interesting submersible purse winch currently under development, which has the advantages of imposing less strain on the purse line, thus making it possible to use thinner purse wires. Probably a greater advantage is the ability to purse at the lowest possible point so that a large volume of water is filtered. However, the pursing depth is limited by the depth of the bunt. The future usefulness of this device depends also on the behaviour of fish schools in relation to it.

Torban compares customary side purse seining with stern seining and the new bow seining method. The method in which pursing, hauling and removing the catch are carried out from the stern, has been discussed before but I expect further remarks will be made during the discussion. The main advantage is that the sail area of the vessel is decreased markedly which results in less strain on the net—an important factor for big vessels in rough weather. In bow seining, pursing and hauling is carried out from the bow, but shooting is from the stern in the usual way. The advantages of this method are less hazard of entangling the net in the propeller and reduced sail area. Since the end of the seine shot first will also be hauled in first, it would seem this method requires a bunt at both ends of the net.

The unfavourable prognosis for herring fisheries in the North Atlantic may result in the exploitation of herring stocks by small specialized fishing vessels as pointed out by **Hamre** and **Nakken**. The collapse of these fisheries has caused serious difficulties for purse seiners originally unfit for other fishing operations—trawling for instance. This indicates the need for combination vessels which can be used in various fisheries with different fishing gear. In this connection attention is drawn to **Kristinsson's** paper which was discussed earlier.

Allen (USA) Chairman: One of the points brought out in the Rapporteur's summary was the need for a net-stacking mechanism. This is a period in the fishing cycle which requires the greatest number of men on a purse seiner today, and I would like to ask if there are any comments concerning mechanisms of this type. One of the other points raised in several of the papers is the desirability of developing a purse winch which would close the net from underwater. **Bardarson** had some comments in his paper and I was wondering if he had any experience with this in Iceland.

Bardarson (Iceland): I do not have much to add to what is stated in my paper. I think the Norwegians have had more experience with this.

Nilsen-Nygaard (Norway): Some trials have been made with a hydraulically driven underwater purse winch in Norway. The design is compact and the tests made so far suggest that the method is promising and feasible for nets up to 85 fm in depth.

Freedman (USSR): In the USSR during the last decade we have used larger vessels with greater ranges, resulting in greater vessel and fleet productivity. The main trend in the development of gear handling equipment has been towards multi-purpose winches controlled from a central position. Technologists working on stern seining have decided that the method has promise.

Allen (USA) Chairman: Has anyone had experience with hauling the seine from the bow of the vessel or by hauling both wings simultaneously?

Petrich (USA): The Sverre Jangaard method employed a conventional type seine which was operated with two power blocks, one on the bow and one on the stern, but the handling of the net was difficult and no time was saved. During the first trip of the vessel *Clipperton*, the method was changed to the conventional operation, except that two blocks were still used; one to haul the net from the water and the second to transport the net to the stern area for stacking.

Williams (South Africa): Eighteen months ago all purse seiners in South Africa were of the conventional one-block type, but there is a tendency now to use the two-block system with the bunt located about three-quarters of the way along the seine. A small block is mounted forward and a large one aft. The main use of the forward block is to dry-up the net and recover the bunt. The only disadvantage is that the net must be restacked before setting. However, this is not a major problem since that wing is relatively short, and overall, this method is much faster than the conventional.

Another development of interest for small seiners working in rough water is the use of outboard-mounted side thrusters, as the use of skiffs is not favoured in South Africa because of the adverse sea conditions. The thrusters are of about 100 hp with 360° traverse. Situated nearly amidships on vertical rails, they are lowered down these rails when required. They are mounted on the port side, and the net shot from starboard.

Allen (USA) Chairman: Since stacking the net is the critical time in the fishing cycle, doesn't this require additional men?

Williams (South Africa): Yes, more men are required but the present crews are somewhat larger than necessary so the total number of men aboard is not increased.

Allen (USA) Chairman: Drums have been used on the west coast of Canada, in the United States and in Alaska, but **Hester** has described the application of this to the fishery in California. Do you know what the crew requirements were in that case, Mr. Green?

Green (USA): The drum seiner requires only four or five crew as opposed to ten for a conventional seiner. These seines are about 25 fm deep and 220 m long.

Allen (USA) Chairman: Is there any comment on the application of this type of drum to other fisheries, such as herring, anchovy or sardine, in other areas?

Allers (Norway): Having studied this paper, three factors appear to limit the system's usefulness. The difficulty of repairing nets when the net is wound on a drum; limitation as to the size of the net which can be handled; and the need for adjusting the rate of hauling of the float and leadlines during hauling when the seines are hung loose, as in Scandinavia. I don't think you can get this adjustable feature with a drum whereas you can with the deck-mounted power block.

Petrich (USA): In Canada all of the west coast herring purse seiners already have or are converting to the drum seine and they are using the same nets used for power block seining. These nets are up to 40 fm deep and there are no problems with a crew of five or six men in place of the previous nine or ten. It's working out quite well.

Goodlad (Canada): On the west coast of Canada where the drum is in use, there is no herring seining. On the east coast, where a few of the west coast herring seiners are working, the drum has not been introduced. There is some talk that it will be, but so far it isn't in use.

Petrich (USA): Just one point about herring fishing on the west coast of Canada and the United States. I know that herring have almost disappeared but they are used for bait—mostly for crab bait and for fresh fish—and there are three boats drum fishing in Washington using the large seines. One example is a seine of 240 × 41 fm on the drum.

Nilsen-Nygaard (Norway): Drum seining appears to be a very promising method for improving working conditions for fishermen, but it also appears that significant problems would occur when handling a large catch. In Norway we use the deck-mounted power block for drying-up the bunt. It is difficult to see how a drum can do this.

Hellevang (FAO): When large catches are obtained, a strapping operation is needed for hauling the net when using the overhead block. That could be saved if the vessels were fitted with deck-mounted power blocks. The net drum is impractical in the Peruvian fishery because of the large bulk of the nets now in use.

Traung (FAO): One problem with a drum seine is that it is prohibited in Alaska. There would be more drum seining if it had not been outlawed there.

Allen (USA) Chairman: Yes, I believe this is the case. In Alaska they had, in about 1955, restricted the use of the drum because it was at that time used only by vessels from the State of Washington which came north for the summer season. The local fishermen felt this put them somewhat at a disadvantage. In any case, vessels from the State of Washington fish with power blocks in Alaska and convert to a drum for the late summer season in Washington and use less men than when fishing with the power block.

Bardarson (Iceland): Regarding the stacking problem, it might be of interest to mention the development of the Icelandic vessel types. With the increasing size of the purse seine, those vessels which had before placed the net on the boat deck aft had to open up a part above the poop to get space enough by storing the net on the main deck at the stern. This means a better trim but some loss of form stability of the vessels. As you know, due to the very heavy loading of Icelandic vessels, we have not much freeboard, even negative ones as you have seen in films and pictures, and we need the watertight poop to ensure stability. This loss was of course partly compensated for by the fact that we got the weight lower down, and these problems I am sure you have been faced with also in other ship types.

Doust (Canada): A Canadian designed combination vessel, rigged for midwater and bottom trawling, can also be easily used for purse seining. We've split the hold into three longitudinal parts which reduces the stability problem to 1/27th of what it would normally be. There are 3 trunk hatches, so loading can be straight in if it is herring; or, if white fish, can go down the after end to the processing deck. Another feature is that we use a Sea Loader hydraulic crane aft instead of the conventional A-frame and this can be used for unloading purposes and for moving the trawls around on deck. It can also be used for handling the seine skiff if needed and for other jobs that can be controlled by one operator rotating the Sea Loader crane through 360°. In a cold environment the operator would be in a heated fibreglass cupboard. In areas where labour is relatively costly the crane can effectively reduce the working crew by up to four men.

Goodlad (Canada): I would like to make a comment regarding the stacking problem of seines. **Torban** states that the reason for the overhead power block arrangement is to use the weight of the part of the seine which is past the block as an active force for saving manual labour. Talking to fishermen I've heard that the use of the high overhead block is simply a left-over from the days when it was necessary to strap in the seine with a high boom and the longer the boom the longer the fleet-in, and there is some evidence that boom lengths are decreasing all the time with the use of power block. I would

like to hear some comments on the relative efficiency or ease of use of the boom-mounted power block and the deck-mounted power block.

Allen (USA) Chairman: **Torban** has given in his paper the drum friction formulae, which are well established textbook formulae applying to devices such as the power block. Although not stated in his paper, it is a flat roller which he describes. A similar formula using the angle of the side of the sheave would apply to power blocks. This requires a tailing force as a line on a gypsy or a warping head requires a tailing force and therefore this is really a force multiplying device and does require some weight of net or pulling on the back side of it to create a pulling force on the net coming from the water. So the height does have the effect of creating more force on the back side and therefore more force in hauling the net from the water. The highest blocks seem to be those in the California tuna fishery. I think this is a matter of gaining speed in hauling. It is my understanding these nets are hauled at very high speed at approximately 30 fm (55 m) a minute which is higher than **Torban** describes at 12 to 15 metres a minute.

Petrich (USA): On Californian tuna purse seiners, the mast is usually amidships or even forward of amidships and all the stacking is done on the very stern of the vessel, especially with the turntable, so to reach this area the boom must be very long and still not be so low as to reduce the pulling force. We know the higher the block the better it pulls.

Allen (USA): What about this problem of loading and unloading fish? Have there been any vessels designed where fish are pumped out of the ship with the vessel's own equipment? How about unloading things like shrimp? In Alaska we have this problem now and they've tried pumps and they haven't worked too well to date. Has anyone a solution to this problem?

Goodlad (Canada): In Canada the pumps of vessels are sometimes used for unloading herring to carrier vessels and to the factories, if the factory pumps break down. This tends to be a makeshift arrangement, but provided sufficient water can be supplied to the hold and sufficient hose is available it works quite well.

Kristjonsson (FOA): It occurs to me that at least two examples of pumping fish out of the vessel should be mentioned. In Iceland capelin is normally pumped out of the vessel with the same pump as is used for pumping from the net into the ship. There is a photo in **Gislason's** paper on Icelandic herring purse seining illustrating the equipment. When this is done the water/fish separator is hoisted off the vessel on to the jetty. In Newfoundland I have seen an air vacuum principle used for sucking cod and other iced fish out of vessels at a good rate.

Petrich (USA): The Marco pump has been used frequently to unload anchovy from the boat and in fact, in one case, 60 tons were unloaded in 30 minutes.

Nilsen-Nygaard (Norway): When we began using submersible pumps in the Norwegian fisheries, it was soon realized that an additional bonus was obtained by being able to pump the dead fish from the bottom of the bunt. This relieved the weight on the bunt which both reduced tension on net hauling devices and minimized the hazard of breaking the bunt. Pumping is now sometimes done in 40 to 45 metres depth, especially in the mackerel fisheries. Pumps are also used in capelin trawl fishing. This has proved to be very successful and is becoming the standard for capelin trawlers.

Reis (Portugal): Pumps are not yet used in Portugal in the sardine fisheries because trials have shown that the quality of pumped sardines is poor and unsuitable for canning. In order to get the highest grade products the fish is taken on board from the net in a kind of mesh basket. Improved pumps should therefore be made which do not damage the fish.

Gronningsaeter (Norway): Many pumps are used incorrectly. Fishermen either use full speed or stop. They should be taught by the manufacturers to use intermediate speeds so as not to damage the fish.

Paz-Andrade (Spain): What is the percentage of damage by pumps in the different fisheries of the world?

Nilsen-Nygaard (Norway): There is no easy answer to this. It depends on many factors such as speed of impeller, type and size of fish, size of pump and amount of water compared to fish. With regard to instructing the fishermen about the use of the pumps, the problem is too little feedback from the industry. Those vessels given instructions seem to overlook these when they have large catches alongside and want to save them.

Sams (Chile): In Chile the Marco Capsule pump is used with good results on sardines and we have found three major important features associated with good quality: as large a pump as possible; low speed; and not drying the catch tightly. The canneries are very satisfied with the quality of the fish pumped in this way.

Green (USA): On the west coast of the USA when pumping squid experimentally we have found damage to squid is reduced by increasing the size of the pump. In this experiment, conducted by the US Bureau of Commercial Fisheries, squid attracted by lights are being pumped directly from the sea without the use of nets. Catches of up to 80 tons per night have been obtained with this method.

Goodlad (Canada): Concerning the percentage of herring damage in eastern Canada using a Scandinavian-type boat, net and submersible pump; after the catch is unloaded with a vacuum pump some 10 per cent of the herring on the factory floor were damaged. Some of this damage was probably done in the factory or in transfer from the holding bins. So that in this experience something less than 10 per cent might be taken as damaged in the two pumpings: net to boat and boat to factory.

Barros Feu (Portugal): Wanted to know if experiments have been made especially with sardines and what the results were.

A. Paz-Andrade (Spain): Spain is now developing a fish pump with a special design of the suction system, so that the fish do not go through blades or rotors thus assuring that scale loss will not surpass 2 per cent. This pump is to be used to transport food fish (sardines).

Thorsteinsson (Iceland) Rapporteur: The next subject, the effect of noise on purse seining, is a problem in many fisheries and particularly in purse seining. In the Atlanto-Scando herring fishery the seriousness of this problem is evident. It has been reported that some vessels have been unable to approach a school because of an extremely high noise level. In spite of the seriousness of the problem, it is surprising how little has been done in this field, judging from the few papers that have been presented at this Conference. **Doust** and **Logan** describe the problems of vessel noise in detail and how they can be minimized. **Olsen** shows a diagram of the average distribution of recorded noise of ten purse seiners. Comparing

this diagram with the hearing ability of herring it becomes evident that herring are able to hear the vessel noise farther away than is necessary to avoid being caught even by the large purse seines used today. Since we know that the sea itself is by far the noisiest element, perhaps this fact makes purse seining and many other fishing methods possible. In view of its indicated importance, the reaction of fish to noise should be a principal object of study. It has been reported that herring schools make no reaction to vessel noise if the engines are at full speed, whereas an escape reaction can be observed as soon as the vessel slows down. The question is whether the herring know that the vessel at full speed is harmless. Have herring acquired the knowledge that only vessels travelling at reduced speed mean danger? A few articles have been written on the learning ability of herring; in many cases this species seems to be very clever at avoiding both purse seines and mid-water trawls. There are a number of examples of such behaviour. It is therefore encouraging that **Olsen** states herring are not as clever as often assumed. **Mohr** leaves this open to question. A great deal of work is needed regarding the reaction of fish to vessel noise, gear noise and other stimuli. In this connection many parameters such as hydrographical conditions, age of the fish, food and biological conditions must be taken into consideration, as is so often emphasized. **Bardarson** presents noise spectrums of three different purse seiners at various speeds. These measurements will be of interest for comparison with measurements from other types of purse seiners.

Vessel noise has one advantage in purse seining. When a purse seine has been shot there is a big gap under and behind the vessel through which the school could escape. During pursing, the vessel noise helps prevent escape of the school through the opening. We also know about other methods to keep the schools away from this gap such as submerged blinking lights or chemicals which make the sea cloudy. These methods are used today in the USSR fishery and perhaps in the Norwegian fishery, but very seldom in the Icelandic fishery. Finally, I am reminded that **Traung** said two days ago that an argument against side thrusters is the noise. I don't believe the Icelandic skippers who have used this equipment agree with him.

Olsen (Norway): Solutions to problems of vessel noise will be to reduce or modify the noise generated. This can in some cases be achieved by handling the vessel properly. There is, however, still a need for further knowledge regarding favourable noise characteristics for a vessel. With regard to sonar noise influencing fish behaviour, it should be realized that the frequency response of fish is such that the sound from sonars cannot be perceived by fish—unless the equipment is transmitting spurious low frequency signals through some fault in the system.

Doust (Canada): First of all, I would like to say that the paper by **Logan** and myself is a condensation of about 4 months' work which was specifically concentrated in the field of design of fishing vessels emphasizing reduction of radiated noise. Also, the original manuscript included detailed design diagrams for specific cases of noise and vibration attenuation from the hull.

I think it's rather remarkable that less than 5 per cent of commercial fishing vessels have really had any serious attention paid to their noise and vibration characteristics. These have a double effect on operations. There are the possible effects on the behaviour pattern of the fish and the reported effect as related to the design on the acoustic and fish detection equipment on board. This, I think, is a rather remarkable fact and for that reason we have been concentrating in this field for several years.

It might be helpful at this stage to itemize the main areas of vessel noise and vibration sources. Firstly, we have the hull structure itself. Bad connections in bulkheads and longitudinal members and the panel structure all affect the radiated noise problem. There are certain clearly established principles in relation to these which should be used in designing the vessel. The next area is the main machinery system with its oscillatory forces and couples which can produce serious vibrations. There are also sub-systems of the equipment and auxiliary machinery devices for other systems which, due to their higher frequency, can be a serious source of noise and vibration. The piping systems in vessels, all the fluid systems, can be extremely noisy. The last main source of noise is the ventilation system and again special provision, with acoustic damping particularly, important reductions in noise source levels can be made in that system.

It might be helpful if we look back at what has been the general practice with fishing vessels which have, mainly, single propellers exposed clear of the hull surface, and associated rudders. All of these devices are very serious noise sources and they can have a material effect on the fishing ability of the vessel. With a view to reducing as far as possible these conventional propeller systems, the Y-pass system as described by **Doust** and **Logan** has been developed. It may be of interest if I itemize very quickly some of the side effects that have been achieved in producing that system. The main thing is that the propeller has been replaced with two impellers which are contra-rotating; and these and the rudders are placed entirely within the hull. For additional protection against the entanglement of nets, there is a grid provided at the aft end. There is a side effect of providing these two smaller impellers in that the race coming out of the central duct is more uniform and the rotation of the wake is cancelled. The rotation of the propeller race has had some adverse effect on the behaviour of larger trawls in particular. The flow into the propeller system is much more uniform than provided by a conventionally exposed propeller and this again is a reason for the material improvement in the noise and vibration levels.

Another important aspect of the device is that the propulsive efficiency is no longer dependent on the shape of the after body of the vessel and as a result it is possible for the designer to make the after end rather fuller than would normally be the case and in this way increase the effectiveness of the design.

We have heard much about lateral thrust units which are generally limited, depending on the size of the vessel, to a few hundred hp. With the Y-pass system, it is possible to use the main engine to exert sideways thrust up to 50 per cent of the main ahead or astern power. So it has a dual capacity in providing lateral thrust and manoeuvring sideways which is quite important for many fishing operations. The specific pull available from the propellers is augmented by approximately 70 per cent which compares with about 30 per cent at the bollard for a Kort Nozzle.

In trawling, occasionally the whole gear becomes fast and a feature which has been discovered about the system is that the stopping distance is about 60 per cent of the conventional system which means the tension on the warps can be reduced considerably faster.

Heinsohn (Germany): With regard to **Doust** and **Logan's** paper I would like to say that the first vessel with a Kort Nozzle looked very much like the Y-pass proposed by **Doust**, but **Kort** learned that it was sufficient to have a nozzle around the propeller in order to improve towing capacity. Furthermore, I think the uneven flow to aft of the overlapping propellers will have some effect on both vibration and noise.

Campion (UK): **Doust's** remarks were very interesting and I would like to learn what the cost element is of a quiet vessel such as he has described.

In the UK we are working on the problem of vessel noise in purse seining and intend to investigate the noise spectra of British purse seiners over an acoustic range and subsequently relate the results to the fishing performance of the vessels. We feel that noise disturbance is sometimes blamed for lack of success in purse seining when, in fact, the main cause is faulty vessel handling.

We have found that herring react strongly to any change in noise level but appear to get accustomed to steady ship noise at a relatively high level. Successful skippers have learned to use this fact in developing purse seining tactics. They stand off from a school until it settles down. They then circle away from the fish in order to approach at a very steady speed (noise level), set the seine at the same speed and finish the set at a high speed, using the increase of noise (when reversing) to scare the fish into the seine. This has proved to be very effective. We have had one small problem with sonar on a trawler. I think it is generally accepted that if there are no low level frequencies emitted by the sonar there should be no problem of scaring the fish. However, we have had reports from skippers of pair trawlers that sonar signals apparently scare herring schools and there are indications obtained from tests of a vessel over an acoustic range that low frequency side noises might be responsible.

Portier (France): We have observed that a trawler from Fécamp, equipped with a propeller nozzle had better results than trawlers without nozzle when fishing for herring in depths less than 30 m. In greater depths, its catches were the same as those of the other trawlers.

Allen (Chairman): I'd like to put on record some statements related to this subject which have been made outside the meeting. **Sams** said that in Chile they have had experience in observing fish movement from aeroplanes and that they have been able to counteract the movement of fish by utilizing the noise from the vessel by shifting from ahead to astern and also by approaching the fish from different directions. **Alverson** made a statement that before fishermen spend money on noise abatement there should be an analysis made as to what results they could expect from a reduction of noise. **Jakobsson** stated that in his 20 years of experience of watching herring he had not seen any real evidence that herring have been scared by fisheries sonar.

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Synthetic Net Materials for Bottom and Midwater Trawls

A. v. Brandt, G. Klust

Materiaux synthetiques pour les chaluts de fond et les chaluts pelagiques

On a constaté que les fils à filets en fibres synthétiques de différents types (plus particulièrement polyamide et polyester, mais aussi polyéthylène et polypropylène, tableaux I et II), convenaient à la fabrication des chaluts de fond et des chaluts pélagiques. On préfère les fils à filets à brins continus, tordus ou tressés. Le degré de torsion ou de tressage influe sur les caractéristiques des filets. Les tableaux III à X donnent quelques exemples des qualités des fils à filets employés pour les chaluts. Les qualités exigées des fils à filets pour chaluts de fond ou pour chaluts pélagiques sont très différentes. Cela est particulièrement vrai pour l'extension et l'élasticité des filets. On étudie d'autres caractéristiques, telles que la rèsistance à la rupture, la résistance à l'abrasion, la résistance à l'avancement, la régularité des mailles, la densité et la résistance aux produits chimiques, aux attaques biologiques et aux facteurs météorologiques. Les procédés de teinture et de raidissement sont mentionnés, ainsi que les avantages des fils synthétiques pour la fabrication mécanique des filets à noeuds simples et doubles. L'emploi de nappes sans noeud risque d'influencer, par la suite, la confection des chaluts. Pour finir, les auteurs étudient l'influence des fils à filets synthétiques sur la sélectivité des chaluts. Ils estiment que l'extension, l'élasticité et la flexibilité constituent des caractéristiques physiques des fils à filets importantes pour la sélectivité. Il faut souligner qu'il existe un lien étroit entre toutes les caractéristiques des fils à filets. Si l'une de ces caractéristiques est modifiée, toutes les autres en subiront le coutrecoup.

Empleo de materiales sintéticos para la fabricación de redes de arrastre bentónicas y pelágicas

Los hilos para red de diferentes fibras sintéticas (especialmente poliamidas y poliésteres, pero también polietileno y polipropileno, Cuadros I y II) han resultado adecuados para la fabricación de redes de arrastre bentónicas y pelágicas. Se prefieren los hilos de filamento continuo, retorcidos o trenzados. El grado de torcido o de trenzado influce en las propiedades del material. En los Cuadros III a X se dan algunos ejemplos de las propiedades de los hilos empleados en la fabricación de redes de arrastre. Las características de los hilos para red difieren notablemente, sobre todo por lo que se refiere a la extensión y elasticidad, según se destinen a redes de arrastre bentónicas o pelágicas. Se examinan también otras propiedades de los hilos, tales como la resistencia a la ruptura y a la abrasión la resistencia al remolque, la estabilidad de la luz de las mallas, el peso específico, y la resistencia contra los productos químicos, la acción biológica y las influencias meteorológicas. Se trata, además, del entintado y de la rigidez del hilo y de la conveniencia de los hilos sintéticos para la fabricación mecánica de redes de nudos sencillos o dobles. El empleo de malla sin nudos puede influir en lo futuro en el diseño de las redes de arrastre. Por último, se examina la influencia de los hilos sintéticos en la selectividad de los artes. La extensión, la elasticidad y la flexibilidad son propiedades físicas de los hilos para redes que revisten importancia para la selectividad de éstas últimas. Conviene insistir en la estrecha correlación que existe entre todas las propiedades de los hilos para redes: si una se altera, todas las demás resultarán afectadas.

FOR many centuries only a limited number of natural fibres was available for netmaking. Many fisheries had one type of fibre only, therefore it was scarcely known how far properties of fibres and net materials could influence efficiency of gear.

Only when synthetic fibres were introduced did it become possible to select different materials for different gears, but this required determination of the most important properties of synthetic materials. The better these properties are known, the better it will be possible to employ the materials most appropriately. In the beginning resistance against rotting was considered the most important property of synthetics; the possibility of changing the properties of net materials by using different types of synthetic fibres and also different composition and construction of netting yarns was neglected for a long time.

There is probably no synthetic man-made fibre which has not been tried in fisheries, but only a small group is really suitable, especially for trawls (see Table 1).

TABLE 1. MOST IMPORTANT SYNTHETIC FIBRES USED FOR TRAWLS

Polyamide (PA) * 1.14 g/cm³	*Polyester* (PES) 1.38 g/cm³	*Polyethylene* (PE) 0.96 g/cm³	*Polypropylene* (PP) 0.91 g/cm³
Amilan	Dacron	Akvaflex	Akvaflex PP
Anid	Diolen	Cerfil	Courlene PY
Anzalon	Grilen	Corfiplaste	Danaflex
Caprolan	Grisuten	Courlene	Drylene 6
Dederon	Tergal	Drylene 3	Hostalen PP (HD)
Enkalon	Terital	Etylon	Meraklon
Forlion	Terlenka	Hiralon	Multiflex
Kapron	Tetoron	Hi-Zex	Nufil
Kenlon	Terylene	Hostalen G	Prolene
Knoxlock	Trevira	Laveten	Propylon
Lilion		Levilene	Pylen
Nailon		Marlin PE	Ribofil
Nailonsix		Norfil	Trofil P
Nylon		Northylen	Velon P
Perlon		Nymplex	Vestolen P
Relon		Rigidex	
Roblon		Trofil	
Silon		Velon PS (LP)	
Stilon		Vestolen A	

Many trade names of synthetic fibres are combined trade names, consisting of the generic name of the fibre and the name of the manufacturing company or country. They are not listed in this table. Some examples are: Bri-Nylon, DuPont-Nylon, Rhodiaceta Nylon, Toray Nylon, Bayer-Perlon, Enka Polyester, Imperial Polyolefine, Toray Pylen.

*fibre density (specific gravity).

Other well known synthetics like polyvinylalcohole, polyvinylidenechloride, polyvinylchloride may also be found in trawls, but they are not considered really suitable for this type of gear.

There is even a tendency to further reduce the number of synthetic materials for trawls. For selectivity research by ICES, all countries trawling in the Northern Atlantic have been asked for the material used for codends in heavy trawls (see Table 2) (v. Brandt, 1969).

TABLE 2. FIBRE MATERIALS USED IN CODENDS OF DEEP-SEA TRAWLS IN THE NORTH ATLANTIC

	Manila	*PA*	*PE*	*PES*	*PP*
Belgium		+	+		
Canada		+	+	+	+
Denmark		+			
Finland		+			
France		+			
Germany (Fed. Rep.)		+	+		
Iceland			+		
Ireland		+	+		
Italy		+			
Netherlands		+			
Poland		+			
Portugal			+		
Roumania		+			
Spain		+	+	+	
Sweden		+	+		
U.K.	+	+		+	
U.S.A.		+			
U.S.R.		+			

The information in Table 2 shows that polyamide and polyethylene predominate for deep water trawling.

There are some difficulties in identifying synthetic fibres even if only the four types in Table 1 are considered. For the identification of these materials, see Klust, 1969; for the identification of synthetic fibres in general, see Miles and Hoffmann, 1961; Boriscev, 1967; Bumiller, 1963 and Textile Institute, 1965.

According to ISO Draft Recommendation No. 1198 (1967) all materials used for netting are named "netting yarn" independent of their construction. As material for netting yarns synthetic fibres are offered in different forms. Trawl yarns are mostly made of continuous filaments, sometimes also of monofilaments. Spun material (staple fibres) or single monofilaments are seldom used for trawls. The same can be said of split fibres or film fibres from filmtapes which are splitting when twisted. Not all synthetic materials are manufactured in all the forms mentioned above.

Netting yarns of two constructions are used for trawls: twisted and plaited (or braided). In general twisted netting yarns are cheaper than braided ones. On the other hand braided yarns are stronger and therefore preferred for codends. They have also a lower extension than most twisted yarns made of the same material. There are different degrees of twist or lay: soft, medium, hard and extra hard. Trawl yarns for bottom trawls are normally medium laid. The degree of twisting or plaiting is of influence on the properties of the net materials (discussed later).

Net materials are designated in different ways. For trawl twines diameter in inch or mm and runnage in yd/lb or m/kg are mostly used. According to ISO Recommendation No. 858 all net materials have to be designated in tex-number. This means the weight in grams of 1,000 m single yarn. For heavy twisted yarns and for all plaited yarns the Rtex-number is recommended. Rtex means the weight in grams of 1,000 m of the total netting yarn. With increasing degree of twisting or plaiting the Rtex-number is increasing but the number of m/kg or yd/lb is decreasing.

Tables 3 to 10 give some properties of netting yarns used for the various types of trawls. The data are obtained by own tests or given by factories. Variations in a wider field are possible, especially due to different degree of twist. Therefore the data are examples only. As far as available, the diameter in mm, the runnage in m/kg, the Rtex-designation, the breaking load (dry) or better the wet knot breaking load is mentioned. The wet knot breaking load is the result of testing a weaver's knot with four bars according to ISO Recommendation Draft No. 1805 (1968). Direct comparison with the breaking load (dry) of a single netting yarn is therefore not possible. For this purpose a more realistic estimate is obtained after dividing the wet knot breaking load by two.

At the beginning only those parts of the trawl were made of PA which are specially exposed to wear and tear like the codline meshes and the codline itself (Klust, 1951; 1). Then the codend and the lengthening piece

TABLE 3. PA NETTING YARNS FOR SMALL BOTTOM TRAWLS, TWISTED

m/kg	*TD*	*tex*	*Rtex*	*Breaking load (dry) kgf*	*Wet knot breaking load kgf*
4170	210× 9	23tex× 9	240	13.5	17
3130	210×12	23tex×12	320	17.5	22
2500	210×15	23tex×15	400	21	26
2080	210×18	23tex×18	480	25	30
1820	210×21	23tex×21	550	30	36
1540	210×24	23tex×24	650	34	40
1390	210×27	23tex×27	720	40	44
1250	210×30	23tex×30	800	42	47
1100	210×33	23tex×33	900	47	52
1000	210×36	23tex×36	1000	49	54
900	210×39	23tex×39	1100	50	56
800	210×45	23tex×45	1250	58	64
770	210×48	23tex×48	1300	63	70
670	210×54	23tex×54	1500	67	74
625	210×60	23tex×60	1600	76	85

TABLE 4. PA NETTING YARNS FOR MIDWATER TRAWLS, TWISTED

m/kg	*TD*	*tex*	*Rtex*	*Wet knot breaking load, kgf*
1960	210× 18	23tex× 18	510	22
1640	210× 21	23tex× 21	610	26
1420	210× 24	23tex× 24	700	32
1290	210× 27	23tex× 27	775	35
1050	210× 33	23tex× 33	950	44
1160	210× 39	23tex× 39	1200	50
730	210× 48	23tex× 48	1570	60
560	210× 60	23tex× 60	1800	78
480	210× 72	23tex× 72	2100	96
360	210× 96	23tex× 96	2800	120
290	210×120	23tex×120	3450	150
213	210×156	23tex×156	4700	200
182	210×180	23tex×180	5500	230
154	210×210	23tex×210	6500	280

TABLE 5.

(A) PA NETTING YARNS FOR HEAVY BOTTOM TRAWLS, TWISTED

ø mm	*m/kg*	*Rtex*	*Breaking load dry, kgf*	*Wet knot breaking load kgf*
1.95	385	2600	138	145
2.05	315	3180	157	160
2.2	294	3400	178	170
2.4	250	4000	210	200
2.6	200	5000	260	250
2.8	175	5700	330	300
3.1	147	6800	360	330
3.5	120	8350	440	400
3.8	90	11200	560	500

(B) PA NETTING YARNS FOR BOTTOM TRAWLS, TWISTED

m/kg	*Rtex*	*Breaking load dry, kgf*	*Wet knot breaking load, kgf*
1900	526	28.4	26.8
1660	600	32.5	30.8
1330	750	40.5	38.4
1150	870	45.0	43.0
1100	900	49.0	47.0
950	1050	53.0	50.8
900	1100	57.0	54.8
850	1180	61.0	58.6
400	2500	136.3	128.2

TABLE 6.

PA NETTING YARNS FOR HEAVY BOTTOM TRAWLS, BRAIDED

m/kg	*Rtex*	*Breaking load dry, kgf*	*Wet knot breaking load, kgf*
590	1700	87	96
510	1960	102	119
400	2460	130	145
350	2820	146	162
290	3500	172	170
230	4300	224	220
205	4900	255	250
140	7000	346	340
114	8800	418	410
104	9600	460	440
94	10600	515	490
82	12200	590	560
72	13800	650	620
57	17500	800	720

TABLE 7.

(A) PE NETTING YARNS FOR TRAWLS, TWISTED AND BRAIDED

m/kg	*Rtex*	*Breaking load dry, kgf*	*Wet knot breaking load, kgf*
2700	370	10	14
1430	700	27	37
950	1050	36	48
710	1410	49	70
570	1760	60	87
460	2170	75	102
360	2800	93	133
294	3400	116	166
225	4440	135	193
190	5300	170	250
130	7680	218	320
100	10000	290	420

(B) PE NETTING YARNS FOR TRAWLS, BRAIDED

m/kg	*Rtex*	*Breaking load dry, kgf*	*Wet knot breaking load, kgf*
2560	390	16.5	23.0
2000	500	20.3	28.6
1610	620	23.6	33.0
1430	700	30.2	42.4
1210	830	32.8	47.2
925	1080	43.2	60.4
780	1280	49.2	68.8
585	1710	65.4	91.6
460	2170	82.0	115.0
380	2630	97.5	136.4
255	3920	134.8	188.8
180	5560	156.0	219.6
134	7460	196.7	275.4

(C) PP NETTING YARNS FOR HEAVY TRAWLS, BRAIDED

m/kg	*Rtex*	*Breaking load dry, kgf*	*Wet knot breaking load, kgf*
415	2400	75	130
295	3400	110	190
200	5000	150	260
160	6250	175	310
135	7400	200	370

TABLE 8.
(A) PP (FILAMENT) NETTING YARNS FOR TRAWLS, TWISTED

m/kg	Rtex	Breaking load dry, kgf	Wet knot breaking load, kgf
2330	430	25	28
1820	550	28	30
1560	640	38	38
1090	920	44	45
840	1190	58	60
690	1440	71	72
520	1920	92	94
440	2290	112	118
350	2820	132	139
300	3300	152	160
210	4700	190	200
177	5640	254	260

(B) PP (FILAMENT) NETTING YARNS FOR TRAWLS, TWISTED

m/kg	Rtex	Breaking load dry, kgf	Wet knot breaking load, kgf
2400	415	26	30.6
2000	500	29	35
1600	625	36	42.6
1360	735	39	46.4
1120	890	44	52.4
750	1330	67	80.8
460	2170	93.2	111.8
300	3300	113	136.4
220	4550	145	174.6

TABLE 9.
PP (SPLIT FIBRE) NETTING YARNS FOR TRAWLS, TWISTED

m/kg	Rtex	Breaking load dry, kgf	Wet knot breaking load, kgf
2560	390	18	24
1250	800	32	44
1010	990	38	48
720	1390	57	71
530	1900	73	91
420	2360	86	108
325	3070	100	117
240	4100	150	175
185	5400	215	240
150	6660	300	340

TABLE 10. PES NETTING YARNS FOR TRAWLS, TWISTED

m/kg	Rtex	Breaking load dry, kgf	Wet knot breaking load, kgf
2210	450	22.2	19.4
1840	540	26.6	23.4
1570	640	31.2	27.4
1380	725	35.5	31.2
1220	820	40.1	35.2
1120	890	43.7	38.4
980	1020	47.5	41.8
900	1100	51.5	44.6
830	1200	56.0	49.0
770	1300	60.5	52.4
720	1390	64.5	56.0
400	2500	90.0	77.8

were made of synthetic fibres, while all other parts remained of manila or other natural fibres to reduce financial losses from damage (N.N. 1949; Klust, 1954). Later on top wings, square and codend only were made of synthetic fibres (N.N., 1957; Ruggiero, 1960). As far as can be seen from the literature, bottom trawls completely made of synthetic fibres were not used before the end of the 1940's. Even today more vulnerable parts like lower wings and even the lower panel of the belly may be made of cheaper vegetable fibres. For hanging and lacing, twines of manila or cotton are sometimes preferred because this creates weak points which give way before serious damage is done to the netting. For fishing on rough grounds sometimes only the upper panels of the trawls are made of expensive synthetic netting yarns while the vulnerable lower parts are made of cheaper synthetic materials like vinylon (polyvinylalcohol) netting (Shimozaki, 1966) or PE-netting (Germany).

SPECIFIC REQUIREMENTS FOR TRAWL NETTING YARNS

The properties of the netting yarn depending on material, fibre type and construction are naturally decisive for the properties of the netting which are further influenced by the process and the type of netmaking. The properties of netting yarn and netting are of main significance for the performance of the gear but aspects of net braiding, repair, handling and storage must also be considered. Since the testing of netting is still problematic, also for trawl materials, usually only the properties of the netting yarn are tested which can be divided into physical, chemical and biological ones. The most striking property of all true synthetic materials is biological, i.e. the resistance against attack by micro-organisms. With natural fibre yarns the decreasing breaking strength caused by biological attack had to be compensated by using stronger, which means thicker, twines, resulting in lower efficiency in many cases.

For **bottom trawls** the netting yarns should combine high wet-knot breaking strength at smallest possible twine diameter, high abrasion resistance, relatively high extensibility under fishing conditions, good elasticity for withstanding shock loads, and no knot slippage or inversion of knots (Klust, 1954, 1958, 1961, 1963; Carter and West, 1964). Therefore, very often plaited netting yarns are preferred for bottom trawls.

Most of these properties are wanted also for **midwater trawls** (Klust, 1963; Schärfe, 1968). High tenacity synthetic twines are considered as one of the prerequisites for midwater trawls. Netting yarns for pelagic trawls apart from good wet-knot breaking strength should have particularly high extension and elasticity. This is needed to equalize differences in the distribution of load in the forenet and thus reduce the danger of bursting through shock loads in heavy seas. Therefore twisted netting yarns are preferred for midwater trawls.

In general, all net-makers will agree with the importance of the mentioned properties for trawl twines, but there will be some differences in the order of importance according to personal experience.

Breaking strength

According to ISO Recommendation No. 1805, the tenacity of a netting yarn is the breaking load per unit resultant linear density of the unstrained specimen in the conditioned state expressed in grams force (gf) per tex. The dry breaking tenacity or tensile strength is of little interest for fisheries for which the wet breaking strength or, even better, the wet knot breaking strength or the mesh wet breaking strength is only important (Carrothers, 1956). Today, the wet knot breaking strength measured according to a generally-agreed technique (ISO, 1968 and 1969) is generally accepted for fishing net materials. For most netting yarns data for one or more of the above kinds of breaking strength are available. Not so much is known about resistance against sudden shock loads (Kajewski, 1958), or the bursting strength of netting, which are both particularly important for trawls.

A comparison of the wet knot breaking strength of trawl yarns made of different synthetic fibres with the same runnage shows a decreasing sequence from PA and PP (both continuous filaments) to PES, PE and PVA (Klust, 1959 and 1962). This gives some hint why PA-netting yarns are preferable for big trawls operated at high towing speed (4 to 5 kn) such as in certain midwater trawling with powerful sterntrawlers and why PVA-netting is sufficient for small otter trawls, or beam trawls operated by small vessels at towing speeds of 1 to 1.5 kn only.

Extension and elasticity

During fishing, netting yarns in trawls are subjected to fairly small loads for most of the time (Schärfe, 1955). Therefore, not only the extension at break (breaking elongation) is important but the whole load elongation curve of the netting yarn because it determines the energy absorbing capacity or toughness of the yarn. Netting yarns with higher extension absorb more kinetic energy and are consequently tougher.

Not only is the extension of interest but also the elasticity, i.e. the ability of recovering from strain without or with a small permanent extension only.

For trawls, a limited extension is wanted to avoid a permanent increase of the mesh size which may result in increased gilling of fish. On the other hand, some extension and, in particular, good elasticity is necessary to reduce the risk of damage due to sudden jerks, e.g. during hauling the trawl with big catches. Good elasticity is especially important for midwater trawls, which can catch big quantities of pelagic fish in some minutes. Trawls made of materials with a low elasticity could then break immediately. Higher extension gives a higher working security (Klust, 1954 and 1966). In this respect PA-netting yarns are considered to have the best properties because they are more extensible than PP-yarns and the permanent elongation of PA is lower (Klust, 1964). This means the elastic recovery of PA is better. Netting yarns made of PE are better than manila. PP and PES netting yarns have a very low extension. This seems to be a disadvantage for trawls of big vessels (Klust, 1961).

The extensibility of netting yarns depends on:

Kind of fibre; Drawing out of the fibre; Construction of the netting yarn; Fineness of netting yarn; Amount of load.

The load-elongation curves of various netting yarns (fig 1) show lowest elongation for PP split fibres. Netting yarns made of PP filament and of PES filament, which are not shown, have very similar curves. Somewhat higher is the elongation of the PE, and PA netting yarns have a relatively high extensibility.

The drawing out, by which manufacturing is finished, gives synthetic fibres their final fineness, diameter, tensile strength and extensibility. The higher the degree of stretching, the higher becomes the tensile strength and the lower the extensibility. In most countries, highly-stretched netting yarns of high tenacity are used for fishing gear.

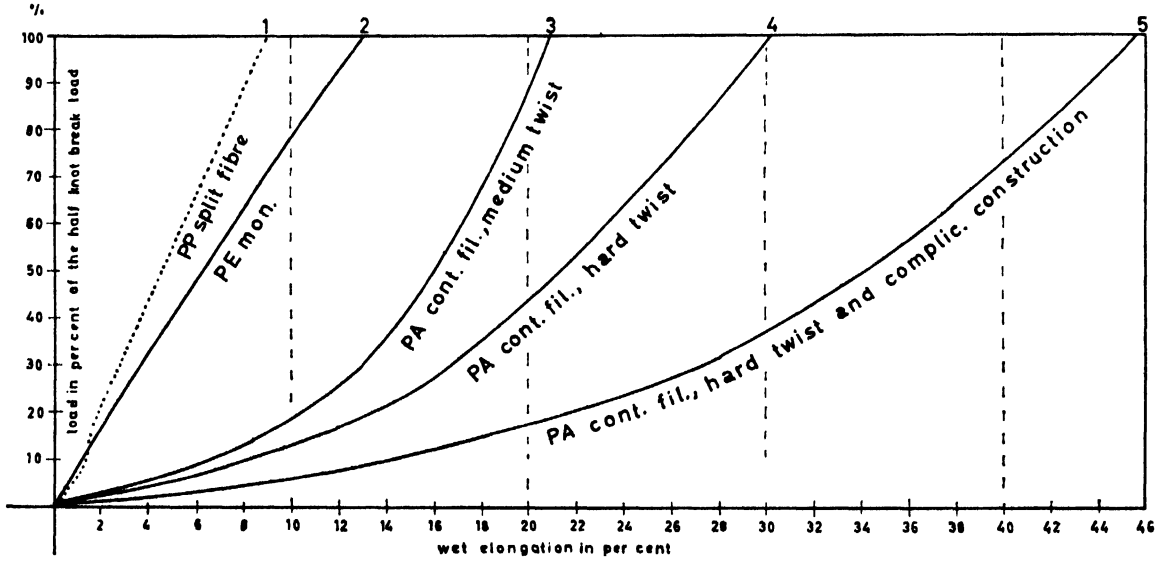

Fig 1. Load-elongation curves of netting yarns

The twine construction factors influencing the extensibility of net material are the manner of folding the single yarns to form a netting yarn and the amount of twist.

Generally, twines obtained by only one folding process will have lower extensibility than cabled twines, which are the products of further twisting operation embracing two or more twines. Table 11 gives two examples for the influence of different twist on the properties of netting yarns. The degree of twist is designated by the coefficient of twist.

TABLE 11. COEFFICIENT OF TWIST AND NETTING YARN PROPERTIES

	23tex × 33		*23tex × 72*	
Coefficient of twist	163	197	155	209
Rtex	857	947	1860	2000
Runnage, m/kg	1166	1056	538	506
Diameter, mm	0.90	1.11	1.45	1.67
Wet knot breaking load, kgf	30	25	121	96
Wet knot elongation, %	16.2	22.0	19.7	31.3

A third example is given by the curves 3 and 4 of fig 1. Curve 3 is the test result of a medium twisted PA netting yarn and curve 4 belongs to a hard twisted PA netting yarn.

If hard twist and complicated cable construction are combined (curve 5 of fig 1) a very high extensibility is obtained.

Under the same load netting yarns of the same type and material are naturally the more elongated the finer they are. A PA-netting yarn of R 400 tex has, for instance, at a load of 4 kgf an elongation of about 12 per cent, while the heavier netting yarn of R 1560 tex has only about 5 per cent (fig 2).

Of course, the elongation of all netting yarns increases with increasing load, but there are great differences with regard to material and construction (figs 1 and 2).

The PA-trawl netting yarn used in the first German experiments in 1951 had the great disadvantage of too high extension which was due to the composition of the netting yarn of very fine multiple twisted single yarns (Klust, 1951).

The fact that higher degree of twisting increases the elongation is the reason why hard twisted netting yarns are used for midwater trawls. For these trawls extension is no less important than tensile strength.

Elasticity is also of interest for net-making. In hand-making with mesh-sticks a netting yarn with high elasticity tends to give a smaller mesh, so that sticks with a larger circumference have to be used (v. Brandt, 1951). On the other hand, netting with high elasticity but without permanent extension has a high stability in mesh size. This is true especially for PA-netting made of yarns heat-treated for twist setting and also for PP-netting which showed no mesh-size changes of more than 3 per cent in practical fishing even after three trips (Carter and West, 1964).

Abrasion resistance

Abrasion resistance which is particularly important for bottom trawls is influenced by type of material, kind of fibre, construction of netting yarn and by its diameter (Klust, 1958, 2). With increasing degree of twist abrasion resistance increases; moreover, braided yarn generally has better resistance than equivalent twisted yarn.

Although it is realized that it is very difficult (if not impossible) to truly imitate the influence of abrasion on net materials during actual fishing, laboratory tests can serve for comparison. Such tests of netting yarns with the same runnage have shown a sequence of increasing abrasion resistance from PVA and cotton over manila, PES, PE and PA (the last three of continuous filament are particularly well suited for comparison, Klust, 1959).

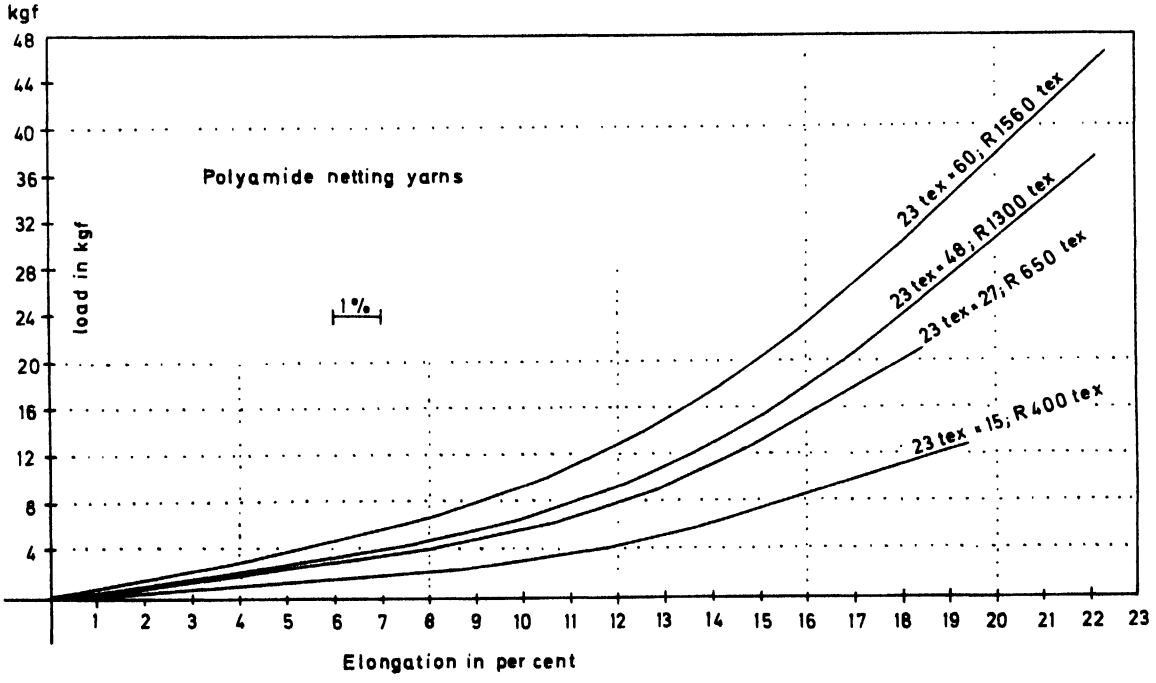

Fig 2. Load-elongation curves of PA netting yarns of medium twist and different fineness (different Rtex values)

Also netting yarn of PP is considered by Klust (1964) to have a high abrasion resistance. Other authors who, with other testing methods, found a low abrasion resistance concluded that PP-netting yarns are therefore not well suited for trawls (Honda and Usada, 1964).

Very often also synthetic netting yarns for trawls are treated, e.g. tarred. This can be done for different reasons such as protection against damage by light, to make material stiffer, to give a better colour for improved catching efficiency, etc. It is well known that tarring increases abrasion resistance (Shimozaki, 1959).

In actual fact, it is not so much the abrasion resistance of netting yarns but that of the knots which counts for both bottom trawls and midwater trawls. On stern-trawlers the knots of the netting suffer, in particular, from chafing against ramp bottom and side walls.

Codends are mostly made of double netting yarns which result in big knots. It has been suggested to replace double netting yarns in codends by respectively stronger single ones, but it was found that then the knots have an even larger volume so suffering even more damage.

Towing resistance

Towing resistance of filtering ability of a trawl depends not only on towing speed and construction of the gear, including shape of meshes and angle of attack of the netting, but also obviously on the diameter of netting yarn and size of knots (Shärfe, 1955; Nédélec, 1963; Poitier, 1967). The filtering ability of a net will increase as the diameter of the yarn and along with it the size of the knots, decrease. This is why bottom trawls requiring thicker netting yarns have to be smaller than pelagic trawls which permit thinner yarns resulting in a better coefficient of filtration (Poitier, 1968).

Stronger materials naturally allow netting yarns of smaller diameter with lower towing resistance—one of the first advantages noted for PA-fibres (N.N., 1949).

It is also known that rough netting yarns made of staple fibres have a higher towing resistance than those made of continuous fibres. In this respect, recent Japanese experiments with trawls made of smooth PA-monofilament are of considerable interest.

Towing experiments in a tank comparing net materials with approximately equal wet-knot breaking strength and equal mesh size demonstrated that, contrary to frequently expressed opinion, plaited netting yarns have no greater towing resistance than twisted ones. At higher speed plaited PA-twines showed an even lower resistance (N.N., 1960).

Netting yarns of PA and PP of the same Rtex values have almost the same wet-knot breaking strength. Since specific gravity of PP is much lower and specific gravity and volume are reciprocally proportional at the same Rtex (and thus wet-knot breaking strength), PP-netting yarns are about 15 to 20 per cent thicker in diameter than PA-yarns (Klust, 1964).

Netting made of double netting yarns (e.g. codends) as well as netting with double knots will have higher towing resistance than comparable netting of single yarns or with single knots. In knotless netting of Raschel type, at equal mesh strength, the diameter of the bars is bigger than in knotted netting of twisted yarns. This seems to compensate the savings of the knots so no difference in towing resistance could be found (v. Brandt, 1966).

During development of midwater trawls great emphasis was put on decreasing towing resistance (increasing filtering ability) to increase towing speed and reduce waves pressure in front of net opening (Schärfe, 1966). In trials, side panels of four panel nets have been made of larger meshes to decrease resistance of this part and, at the same time, to get a higher net opening by the higher resistance and shearing power of the lower and upper panels (Hamuro and Ishii, 1961; Hamuro, 1962). In German one-boat midwater trawls, the lower wings and sometimes also the total lower panel are extended forward to provide a downward shearing effect.

Constancy of mesh size and knot slippage

A net-maker, asked for properties important for trawl netting, will mention constancy of mesh size as one of main items. He will be made responsible by his customer if the netting has incorrect mesh size or if mesh size changes after some time of fishing by decreasing or increasing. The international fishery conventions request a minimum mesh size for wet netting. Bigger mesh sizes are allowed, but in general exactly the minimum mesh size is wanted by the customer and not a bigger one. This causes some difficulties for the net-maker.

The mesh size can alter in water before or during fishing by changes in the length of the netting material or by changes in the tightness of knots and finally by specific features of the use of netting (v. Brandt, 1968). In general, most natural fibres shrink and most synthetic fibres extend in water (Carrothers, 1959). The degree of changes in length depends also on the construction of the netting yarn (Klust, 1956). With increasing degree of twist (and increasing extension) the lengthening of PA-netting yarn in water increases.

Netting is often exposed to high temperatures, e.g. for setting of yarns and knots to stabilize mesh shape, for preparation and for dyeing. This may lead to mesh shrinkage. For some synthetic yarns, shrinkage starts at much less than 100°C, even when the melting points are much higher. Very often it is overlooked that tar products, as are widely used for net preparation, have a boiling temperature of more than 100°C. PA netting treated with this suffers considerable mesh shrinkage and eventually also other damage.

In trawling, a particular cause for mesh shrinkage has been found for netting yarns made of continuous fibres. Especially codends may be stretched by heavy catches in such a way that, after the load is removed, some stretched continuous fibres form loops sticking out of the netting yarn. Examples with a shrinkage of mesh size more than 40 per cent have been found (v. Brandt, 1968; Schwalbe, 1968).

If the knots are not tight, the mesh size can change considerably. This happens with handmade netting which is not stretched after braiding with stretching machines depthwise and also sometimes lengthwise in order to make the knots tighter and more stable.

It is also known that knots can become loose. However, low knot stability or a low resistance against opening of the knots (van Wijngaarden, 1959) must not necessarily

result in changes in mesh size. Knots may become open but not slip. In this case, the mesh size is not changed. Hard twisted yarns have, in general, lower knot stability than softer twisted yarns. Rough twines or netting yarns mixed of continuous and staple fibres give good knot stability. The same can be said of plaited yarns in comparison with twisted ones. With stiff material, double knots are sometimes needed to prevent opening of knot.

Knot slippage, which may occur also with unloosened knots, can lead to offences against international minimum mesh size conventions. Knot slippage generally increases with increasing degree of twist of the netting yarn. Most netting yarns made of synthetic fibres require knot stabilization by net-stretching followed by heat setting and/or dipping in a knot-bounding agent. By this preparation, knot slipping and change in mesh size can be more or less avoided. It seems not possible to avoid mesh changes completely. Extensive tests with codends of trawls show that mesh sizes change differently in different parts (Clark, 1952; Cassie, 1955; v. Brandt, 1958; Richert, 1968).

Specific gravity and buoyancy

For different specific gravities of synthetic fibres see Table 1. This property influences sinking speed of netting material, but it has never been mentioned that sinking speed is of importance for trawls, not even for midwater trawls, However, with synthetic netting yarns with specific gravity of less than one a better shape of trawls was expected.

During one early experiment with trawls made of PA (N.N., 1950) it was stated that in comparison with manila trawls the upper panel of a nylon trawl due to lower specific gravity should give a higher opening. This was also mentioned for trawls made of PE-netting yarns. The low specific gravity and the fact that it did not absorb any water should allow a reduced number of floats leading to reduced drag (N.N., 1959). The same has been said for trawls made of PP-netting yarn—buoyancy of the PP top sections and the PP ropes should not only support the lifting of the headline.

When towing is stopped for hauling or any other reason it is desirable that the aft part of the trawl should collapse to prevent fish escaping. Trawls made of PA-netting yarn will do so and would therefore have less need for a flapper (non-return valve).

Resistance against chemicals, biological attack etc.

Different synthetic fibres are soluble in different chemicals and this is used for identification. It has, however, never been reported that trawls were damaged by chemicals normally used on vessels such as fuel, lubricants, etc. There is some suspicion that ammonia used in deep freezers could cause damage to PA-netting yarns. Fish slime or other offal has no effect on synthetic netting yarns and the same applies (until now!) to water pollution as regards PA (Schoeniger, 1952–53 and 1953). On the other hand, rust can decrease breaking strength of PA-netting yarns. Iron chains fixed on groundropes can therefore cause damage by rust; also dye-stuffs containing iron compound.

Common advantage of all synthetics over natural fibres is complete resistance to rotting. This makes short-life natural fibres often actually more expensive (Fontan, 1958). The resistance of PA-fibres is actually not as complete as was assumed and as is the case with PE and PVC (Demmer, 1968), but the observed effect of fungi on PA-materials can practically not occur in trawls.

As trawls remain for longer periods on fishing vessels or during net repair in harbour in the open and unprotected from weather and sun, resistance against these influences must be considered. Great differences in weathering resistance of synthetic materials have been found (Klust and v. Sengsbusch, 1965; Radalakshmy and Kuriyan, 1969; v. Brandt, 1969). PVC-, PA- and coloured PE-monofilaments have high resistance, followed by netting yarns made of PES- and PVA-fibres. Lowest weather resistance was for netting yarns made of PP continuous fibres and PA continuous and staple fibres.

In trawling deterioration by weather is far less important than mechanical wear, so poor resistance to sunlight and weathering is no serious drawback.

Necessity of dyeing and stiffening

Trawls are active fishing gear, therefore their colour may be of little significance. But bright shining netting may frighten fish. Therefore, for midwater trawls low visibility is wanted and some suggested that upper parts of trawls should have a different colour from side and lower parts (Mel 'Nikov, 1962). Dyed trawls are often preferred by small vessels with low towing speed. Green and blue colours seem preferred. Fibre producing factories offer special dyeing agents which have no, or only negligible, influence on the yarn's physical properties.

In some waters with luminescence undyed trawls are sometimes preferred because it is believed that white trawls are then less visible and have better efficiency.

Synthetic netting is also dyed, often black, to improve resistance to sunlight, but black makes mending difficult (N.N., 1965).

Dark colour may also be a side effect of stiffening agents applied to improve shape of trawls during towing. Additional stiffening is not needed for PE-netting yarns or twisted PA- and PP-yarns made of monofilaments or filmtapes because they are already stiff enough.

Initial rigidity or stiffness of netting yarns impedes netmaking, not only for hand braiding but particularly for mechanical netmaking with powered knitting machines (v. Brandt, 1957).

NETMAKING AND TRAWL DESIGN

Most modern fishing gear is made of machine-braided netting. Heavy bottom trawls, especially those for deep-sea fisheries are, however, still made of hand-braided netting in many countries—because the machines only became available some years ago. Moreover, there are some difficulties in avoiding excessive loss in cutting netting for the traditional trawl designs developed for hand-braiding of manila and sisal.

The first trawl sections made of machine-braided netting were manila bellies. Then it was considered a great advance that manila netting yarns of up to 3 mm diameter could be processed by machines (v. Sengbusch,

1957). Synthetic netting yarns proved to be much easier to handle on net machines, especially when made of soft fibres like PA continuous filaments. The same machine can process heavier netting yarns of some synthetic fibres than of manila or sisal. Some alterations of the net machines became, of course, necessary when changing over from manila with low extension to synthetic netting yarns with generally higher extension. Today, net machines for knotted netting of synthetic fibres are available for the heaviest types of trawls. Modern knitting machines can work with all netting yarns, even as heavy as PA, plaited, R 18,000 tex, double! The new machines can also make all sizes of meshes. Mesh sizes can be altered easily and one operator may take care of two or even four machines simultaneously.

Heavy netting yarns are knitted with single knots only. Double knots are used for e.g. PA-monofilament 0.9 mm diameter, as used for small trawls in Japan. Heavy netting yarns need big shuttles up to 35 mm pitch resulting in a small number, mostly less than 100. Moreover, such machines work with slow speed only, 4–12 rpm. (For finer netting yarns, machines with a speed up to 36 rpm are known.) With increasing demand for machine braided netting, the factories try to make more economic net machines for heavy trawl netting by introducing especially new forms of shuttles or bobbins and new methods of their exchange. For heavy trawl twines, also the auxiliary equipment has to be changed. The power of stretching machines was increased from 1.500 over 4.000 to now 30.000 kgf and new equipment for the setting of heavy trawl twines of synthetic fibres became necessary.

Knotless netting is used for small trawls with small meshes only. For large meshed knotless netting is still too expensive, but there is one feature which may interest future development. It is possible to decrease the mesh size of knotless netting by Raschel machines gradually from row to row. This would allow netting from headline to codend to be in one piece without joinings. Moreover, knotless netting can be made not only in sheets of netting but also in hoses or gunnels. Since, however, the machines cannot yet decrease the number of meshes, new trawls designs would be needed to take advantage of this feature of Raschel netting.

Knotted machine-braided netting can be made of both twisted or plaited yarn. Since the netting machine turns the yarn during knot-making, the number of twists per metre of twisted yarn is affected and the yarn is deformed to a certain extent. This effect does not occur with plaited yarns. At present, about 15% of trawl netting yarn is plaited and the share of this type may increase with continuing increase in demand for heavy trawl material.

TABLE 12. NUMBER OF DIFFERENT NETTING YARN SIZES USED FOR HEAVY DEEP SEA BOTTOM TRAWLS IN GERMANY

	Whitefish	*Herring*
1947 (manila)	6	4
1952 (manila)	5	4
1961 (PA)	—	4 (FAO, 1965)
1969 (PA)	1 or 2	1

Synthetics and machine-braided netting have influenced the design of trawls and in particular reduced the number of different sizes of netting yarns. As an example, in Germany for deep sea trawls (including codend) for white fish and herring the number of netting yarn sizes which was 4 to 6 came down to 1 to 2 (Table 12).

This means that using synthetic fibres for trawls has not only influenced net-making machines, but also, through machine-made netting, the construction of the trawls.

SELECTIVITY OF CODENDS

By international fishery conventions, a minimum mesh size was established for bottom trawls for the Northern Atlantic. By such regulations small fish should have the chance to escape. Most fish try to escape through the aft part of the codend and their size depends on the size of the mesh, etc. The selectivity of a codend is determined from the length of fish of which 50 per cent escape and 50 per cent are retained. The relation between the 50 per cent retention length and the mesh opening is the selection factor (sf).

Experience has shown that selectivity of codends depends on the material and the netting yarn construction. Codends made of manila or sisal retain fish which could escape from codends of the same mesh size made of cotton or hemp. When synthetic fibre yarns were introduced it was found that some have a low selection factor, like manila, and others have a high selection factor like cotton (Table 13).

TABLE 13.

Low sf.	*High sf.*
manila	cotton
sisal	hemp
PE	PA
PP	PES

Jensen (1949) was first to mention stiffness or flexibility of netting yarn as important factors for selectivity of trawls for flatfish. Moreover, the elongation was considered an important property influencing selectivity. It was assumed that meshes made of flexible netting yarns can more easily be stretched or changed in shape according to the cross-section of the fish trying to escape. Therefore, seines of more flexible material tend to have a higher relative releasing effect than trawls. During 1955 and 1958 in the reports of ICES and ICNAF many authors (Beverton, Boerema, v. Brandt, Cieglewicz and Strzyzewski, Clark, Letaconnoux, Margetts, McCracken, Parrish) repeat the opinion that certain characteristics of the gear, like netting yarns properties, are responsible for selectivity which can be modified by changing these properties. "A codend made of thin and relatively flexible twine releases larger fish than one of stiffer material for the same size of mesh" (Boerema, 1956). "At equivalent mesh sizes, meshes of lighter more flexible twines usually give higher escapement than those of heavier and stiffer twines" (Clark *et al.*, 1958). On the

other hand, until now it could not be demonstrated conclusively that the mesh selectivity can be influenced by changing the constructional properties of a netting yarn of the same type of synthetic fibre. Bohl (1967) found that codends made of PP-monofilaments and of PP-continuous fibres had the same sf 3.3 in spite of the considerable difference in flexibility of the yarns.

Up to now, no tests are available to prove that stiffness or flexibility or elongation or any other property are alone or mainly decisive for a high or low selection factor. On the other hand, it is agreed that physical properties of netting yarns may have an influence on selectivity of codends and should be studied in more detail (Joint ICES/ICNAF Working Group on Selectivity Analysis).

Conclusions

The introduction of synthetic net materials, which started early 1950's, has considerably extended possibilities for finding the most suitable material for the different types of trawls. At present, seven chemical fibre groups are available, in the order of their importance: polyamide, polyethylene, polypropylene, polyester, polyvinyl alcohol, polyvinyl chloride and polyvinylidene chloride. In this paper the properties of the first four are discussed.

In spite of this choice, the ideal material for trawls does not exist yet. The four most important requirements of material for large trawl nets: very high breaking strength, relatively high extensibility and elasticity, small twine diameter and high abrasion resistance, can best be complied with by netting yarns made of polyamide continuous filament. Without this net material two important developments in trawl fishing would not have been possible: the heavy bottom trawls for modern sterntrawlers and the midwater trawls for large dimensions.

References

The authors are willing to provide an extensive list of references upon application (see List of Contributors for address).

Comparative Efficiency of Nylon Monofilament and Polyethylene Multifilament Netting for Small Otter Trawls

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Efficacite comparée des filets en monofilament de nylon et en polyethylene pour des petits chaluts a panneaux

Afin d'étudier la possibilité d'emploi du filet en monofilament de nylon (PA) dans les chaluts, on a comparé un chalut de fond classique de pêche côtière avec un chalut similaire dans lequel le grand dos, la plus grande partie du dessus et le voile avait été remplacés par des pièces d'alèze en monofilament de nylon. Les filets ont été remorqués par des chalutiers à peu près identiques (45 CV environ). Ils présentaient une hauteur d'ouverture d'environ 1 m et une distance entre pointes d'ailes d'environ 8 m. Tandis que les prises des vrais poissons de fond étaient presque égales, le chalut en monofilament capturait davantage de poissons semi-pélagiques comme le chinchard et le barracuda. On attribue ceci à la visibilité plus faible du "toit" du filet. Actuellement, environ 1 pour-cent seulement des petits chalutiers japonais emploient le chalut en monofilament, mais l'on espère que celui-ci aura bientôt une diffusion plus large.

Rendimiento comparativo de los paños de monofilamento de nilón y de polietileno para artes de arrastre pequeños

Para determinar la posibilidad de emplear monofilamento di nilón en los paños de los artes de arrastre, se compararon uno normal para la pesca costera en el fondo hecho de polietileno con otro idéntico en el que la visera, casi todo el paño superior y la trampa eran de paños de monofilamento de nilón. Las redes las remolcaron en arrastreros casi idénticos (con motor de cerca de 45 hp). La abertura vertical era de cerca de 1 m y la distancia entre los extremos de las pernadas de unos 8 m. Mientras que la captura de verdaderos peces del fondo era casi idéntica, el arte de monofilamento capturó más especies semi-pelágicas como caballa y barracuda. Esto se atribuye a ser menos visible la sección superior de la red. En la actualidad sólo el uno por ciento, aproximadamente, de los arrastreros japoneses pequeños emplea artes de monofilamentos, pero se anticipa que éstos encontrarán en breve mayor aceptación.

THE species of fish and fish behaviour with regard to the gear are among the most important biological factors influencing the efficiency of trawlnets. Physical factors which influence underwater performance of the trawl and also fish reaction include towing speed, construction of the net, twine material, mesh size, opening size and relative visibility of the gear underwater.

In earlier comparative experiments with small trawls made of cotton and of nylon multifilament netting, the influence of the netting material on the catching efficiency was confirmed (Miyazaki, 1964).

Experiments with nylon monofilament netting

The comparative fishing trials discussed below were conducted during six days in August 1968 on an inshore fishing ground of 15 to 20 m depth. The design of the two experimental trawls was the same and represented the usual type used for commercial fishing by small trawlers. One trawl was made of polyethylene multifila-

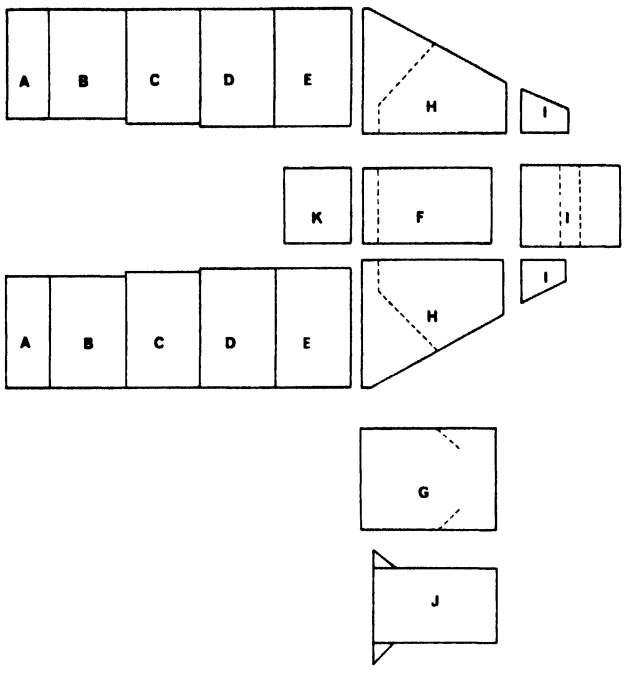

Fig 1. Scheme of the small trawlnet used in trials

ment netting and dyed light reddish brown. In the second trawl the square (K), the upper panel (F) and the flapper (J) were replaced by nylon monofilament netting (fig 1, Table 1). This net was dyed light green.

These small otter trawls are of relatively simple construction and rigging and are easy to operate. The two boats used for the trials were about 9 GT and had engines of 45 hp. Simultaneous comparative tows of one hour duration were made on the same grounds during the daytime only.

TABLE 1. MAJOR SPECIFICATIONS OF EXPERIMENTAL TRAWLNETS

A. Polyethylene multifilament net

Net parts	*Mesh size (cm)*	*Twine size*	*Width (meshes)*	*Length (m)*
Top (F)	2.53	200D 9	150	6.0
Bottom* (G)	2.53	200D 9	200	6.5
Sides* (H)	2.53	200D 9	200–75	6.4
Codend* (I)	2.02	200D 12	200	2.0
Flapper (J)	2.53	200D 9	150	4.0
Square (K)	2.53	200D 9	150	3.5
Square	2.53	200D 9	100–1	3.5
Wings* (A–E)	2.53	200D 9		
Headline*		12 mm		14.0
Warp*		18–19.5–24.2 mm		360

B. Nylon monofilament net

Top (F)	2.53	210D 9 Pile	150	5.8
Flapper (J)	2.53	210D 9 Pile	150	3.6
Square (K)	2.53	210D 9 Pile	150	3.5
Square	2.53	210D 9 Pile	100–1	3.5

*The same materials and specification as of the polyethylene multifilament net were used for these parts of the nylon monofilament net.

Results

According to their natural behaviour and distribution, the fish species caught can be separated into two groups, i.e. semi-pelagic and demersal species. The semi-pelagic group includes barracuda, horse mackerel, butterfish, common sea bass, croaker, squid, cuttle fish, etc. The demersal group includes lizzard fish, conger eel, grey rock cod, green link, flat-fish, shrimp, squilla, octopus, etc.

As can be seen from Table 2, the catches of demersal species were almost equal for both nets, but the catches of semi-pelagic species were about double for the net with nylon monofilament netting.

TABLE 2. COMPARISON OF CATCH-PER-DRAG-DAY OF SEMI-PELAGIC AND DEMERSAL FISH TAKEN IN THE NETS

Date	*Semi-pelagic species caught with:*		*Demersal species caught with:*	
	Nylon mono filament net (*kg*)	*Polyethylene multifilament net* (*kg*)	*Nylon monofilament net* (*kg*)	*Polyethylene multifilament net* (*kg*)
8/1	32	9	5	11
8/3	13	24	14	12
8/4	20	9	29	14
8/5	32	16	15	14
8/10	24	5	20	12
8/11	21	10	3	9

Comment

Great care was taken to have both trawls operate with the same dimensions of opening height (1.0 to 1.1 m as measured by netsonde), opening width (7.9 to 8.0 m as calculated from divergence and length of warps), towing speed (2 kn) and fishing conditions. The difference in catches must therefore be attributed to a difference in fish behaviour. Unfortunately, the gear and the fish were not observed directly during these trials and for the explanation, reference must therefore be made to previous studies.

For catching semi-pelagic fish the efficiency of a trawl can be expressed as the product of towing speed, wing distance and opening height. For catching demersal fish the efficiency could similarly be expressed as the product of towing speed and wing distance, but without the opening height because this would have little influence with regard to these species which live very close to the bottom or burrow into it. Since both trawls were operated in exactly the same way, this explains the insignificant difference in the efficiency for catching demersal species.

For the catch of semi-pelagic species the square and the upper part of the net, together with the opening height play an important role. The significant differences in the catches of both trawls can therefore be attributed to the difference in visibility of the netting in the upper panels; the nylon monofilament netting is transparent and therefore less visible in water than the polyethylene multifilament netting. This is confirmed by the following observations: During the trials barracuda and horse mackerel were found gilled in the upper net near the opening and at the flapper, both from inside and outside in the nylon monofilament netting. This species gilled in the polyethylene multifilament net only from inside close to and forward of the flapper. According to earlier observations (e.g. Miyazaki, 1957) sand borer and croaker go over the headline of small trawls and squid tried to

avoid the net actively, which indicates that this semi-pelagic species can recognize a trawl net. This is of course more difficult with nylon monofilament netting because of its poorer visibility.

Conclusions

Because of its about doubled efficiency for semi-pelagic fish and equal efficiency for demersal fish, nylon monofilament netting in the upper parts of small trawlnets can be recommended for commercial operation. The price of a common polyethylene multifilament net is about $34 and that of the improved net with nylon monofilament section about $56. The promising results have created interest in the commercial fishery and about 1 per cent of the fleet of small trawlers (2 to 9t, 60 to 40 hp) is at present using this gear for inshore trawling in depths of about 20 to 120 m. It is expected that the application of this type of trawl will increase.

Fishing Deck Layout on Stern Trawlers, its Effect on Ship Design and Performance

Tadeusz Sekudewicz

Aménagement du pont de pêche sur les chalutiers à pêche arrière Son influence sur la dessin et les performances du navire

L'allongement du pont de travail qui convient aux grands chaluts en facilitant leur utilisation impose le déplacement des superstructures vers l'avant. Ceci est désavantageux pour le contrôle visuel à partir de la timonerie, malcommode pour l'équipage et les appareils placés dans la passerelle (tanage), et conduit à de sérieux problèmes de stabilité de cap et de perte en traction de remorquage quand on chalute par forts vents traversiers. Ce dernier effet qui est le plus important peut être atténué par une augmentation de la puissance de propulsion et par un déplacement au vent du point de remorque (c'est-à-dire les poulies de potences des funes). Pour augmenter la puissance de remorquage, il faut insister surtout sur la recherche d'un optimum en ce qui concerne le nombre de tours, le dessin et le diamètre de l'hélice, plutôt que sur la force motrice. Par l'adoption du système à deux chaluts, qui consiste à filer un autre chalut pendant que l'on vide et que l'on répare éventuellement le premier chalut, on peut réaliser une économie dans le temps d'utilisation suffisante pour permettre d'effectuer un trait supplémentaire par jour.

Disposicion de la cubierta de pesca en los arrastreros por popa, sus effectos sobre el tipo de barco y su rendimiento

La ampliación de la cubierta de trabajo para poder colocar las grandes redes de arrastre y facilitar su maniobra, obliga a llevar la superestructura hacia adelante. Esto presenta un inconveniente para el control visual desde la caseta del timón así como para la tripulación y el equipo de la caseta del timón (cabeceo) y conduce a serios problemas de la estabilidad de derrota y a la pérdida de fuerza de tracción del barco cuando éste opera con fuertes vientos de costado. El últimofact or, que es el más importante, puede reducirse aumentando la fuerza de propulsión y desplazando el centro de tracción (es decir, los perros de arrastre) hacia barlovento. Para incrementar la fuerza de tracción es necesario dar mayor importancia a las r.p.m. de la hélice y al tipo y dimensiones de ésta. Aplicando el sistema de dos arrastres alternados, por ejemplo echando al agua una segunda red antes de que la primera sea vaciada y eventualmente reparada, se podría economizar suficiente tiempo de maniobra para poder hacer un lance adicional por día.

EXPERIENCE gained by designers, shipowners, operators, exchange of opinions between specialists, observations of world fisheries development and research have, in general, enabled stern trawler construction problems to be overcome. The basic problem for fishing deck equipment is to achieve the shortest working time, minimum number of men and full safety, using simple, cheap and reliable gear.

To fulfil these conditions is no simple task.

By lengthening the working deck, bottom trawls can now be hauled in three heaves; using the same system, it requires five or more to haul a pelagic trawl.

World trends in trawler fishing show that the main propulsion power is increasing, this also means increased pull for the same dimensions of ships, which usually is followed by bigger trawls. In this situation, the number of operations with gear rises again, extending the shooting and hauling cycle, thus requiring new constructional solutions for deck equipment and fishing systems which have to take into account correct layout of accommodation for stores, cargo, engine-room, processing plant and crew.

Influence of a long working deck on above-water layout

Faced with all the demands in a modern fishing trawler, the designer must make considerable effort, frequently having to compromise. To secure maximum deck length means that superstructure and wheel-house may have to be very far forward; this in turn means that control stations are situated far from important working points on deck. In this situation and in bad weather, it is impossible to control the work on deck directly from the wheel-house. Thus, a second control station becomes necessary, which means increasing cost of the ship, the number of crew and a more complicated construction. A second unfavourable influence is that siting the superstructure and wheel-house forward shifts the side wind pressure centre towards the bow.

To keep the ship on course over the grounds in a side wind, external forces must be balanced by swinging the rudder, thus increasing resistance and pull losses. In difficult weather conditions, especially when the ship is trawling and the stern is held by the trawl, the bow suffers much greater pitching and acceleration amplitudes. This has an unfavourable influence on the radio-

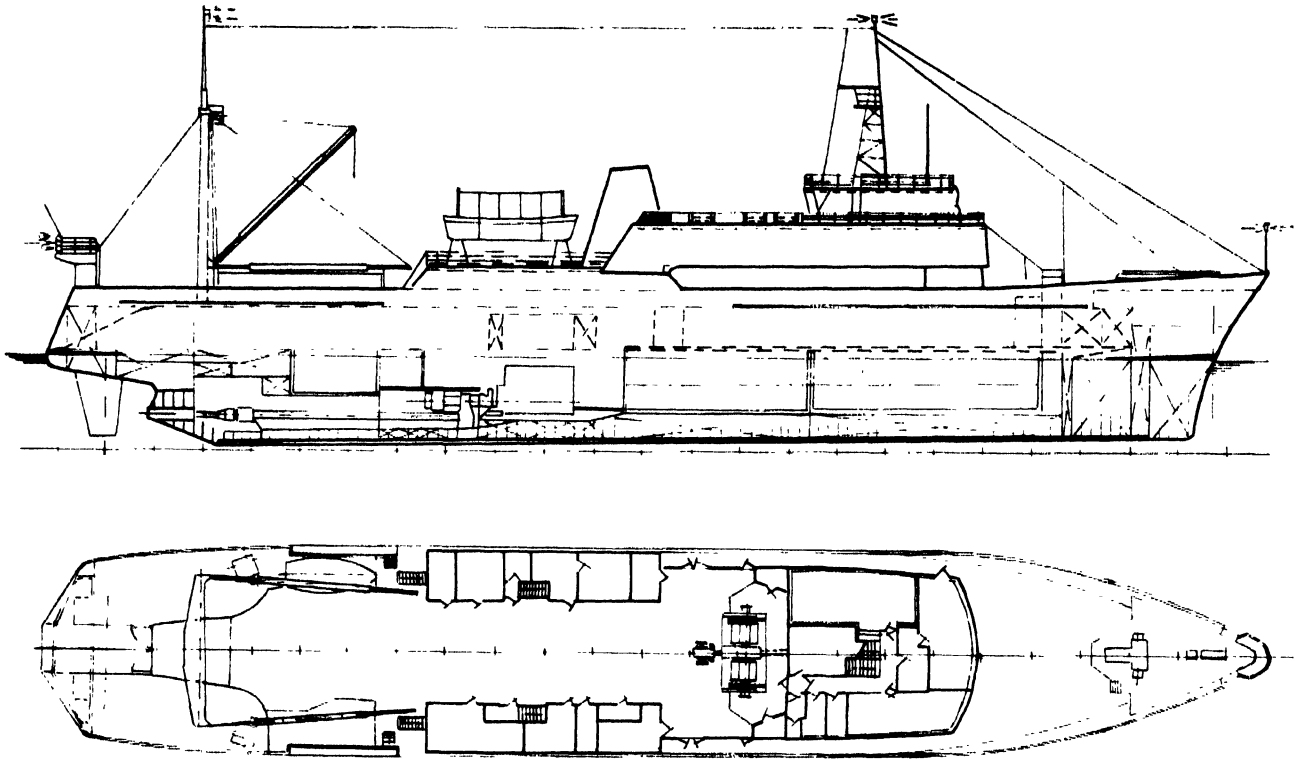

Fig 1. Stern trawler Type B29 with a long fishing deck, one multi-drum trawl winch, two cargo winches, superstructure and fishing-navigating wheelhouse located in the fore part of ship. The centre of the side wind pressure has moved from the centre of gravity to the bow

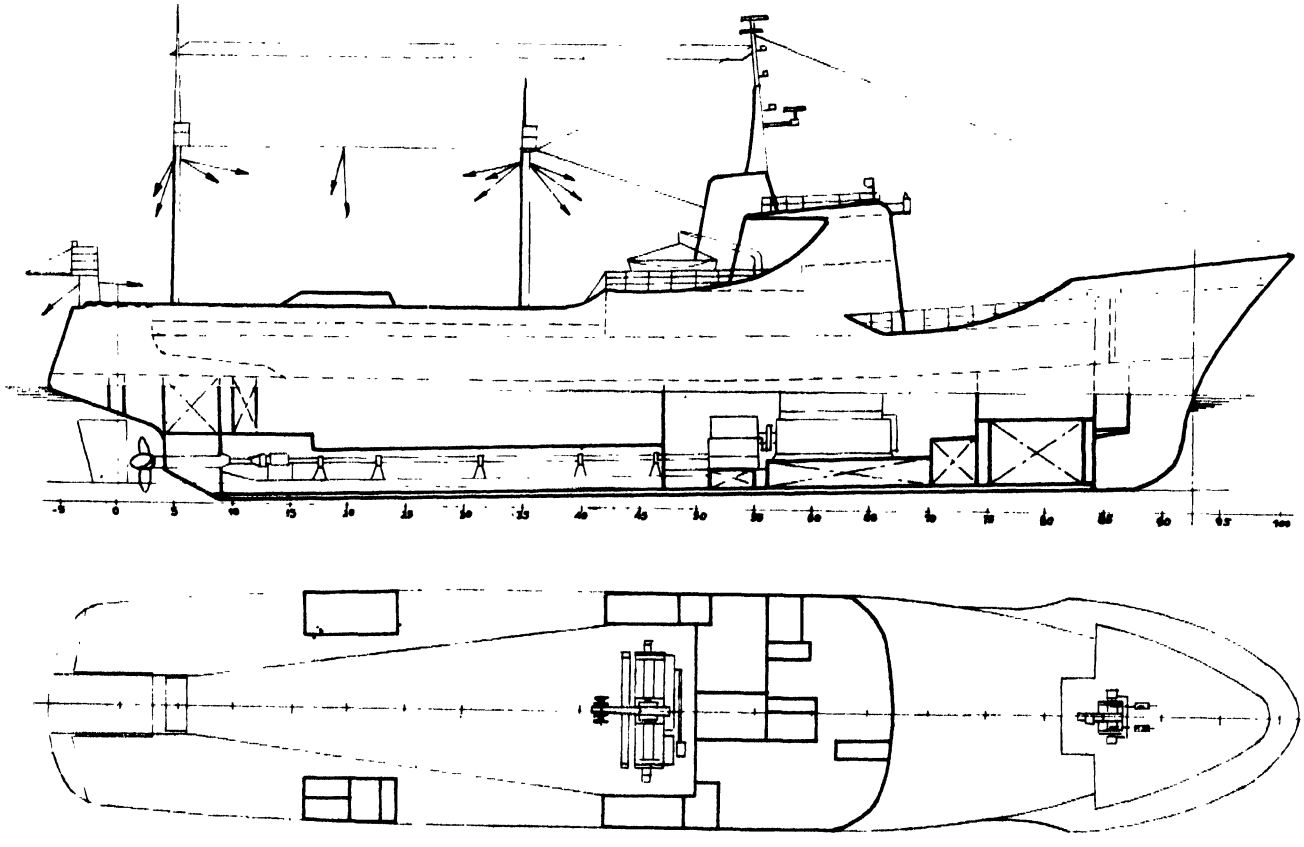

Fig 2. Stern trawler Type B427 with a middle fishing deck, one multi-drum trawl winch, superstructure and fishing-navigating wheelhouse located in the fore part of ship. The centre of the side wind pressure has moved from the centre of gravity to the bow

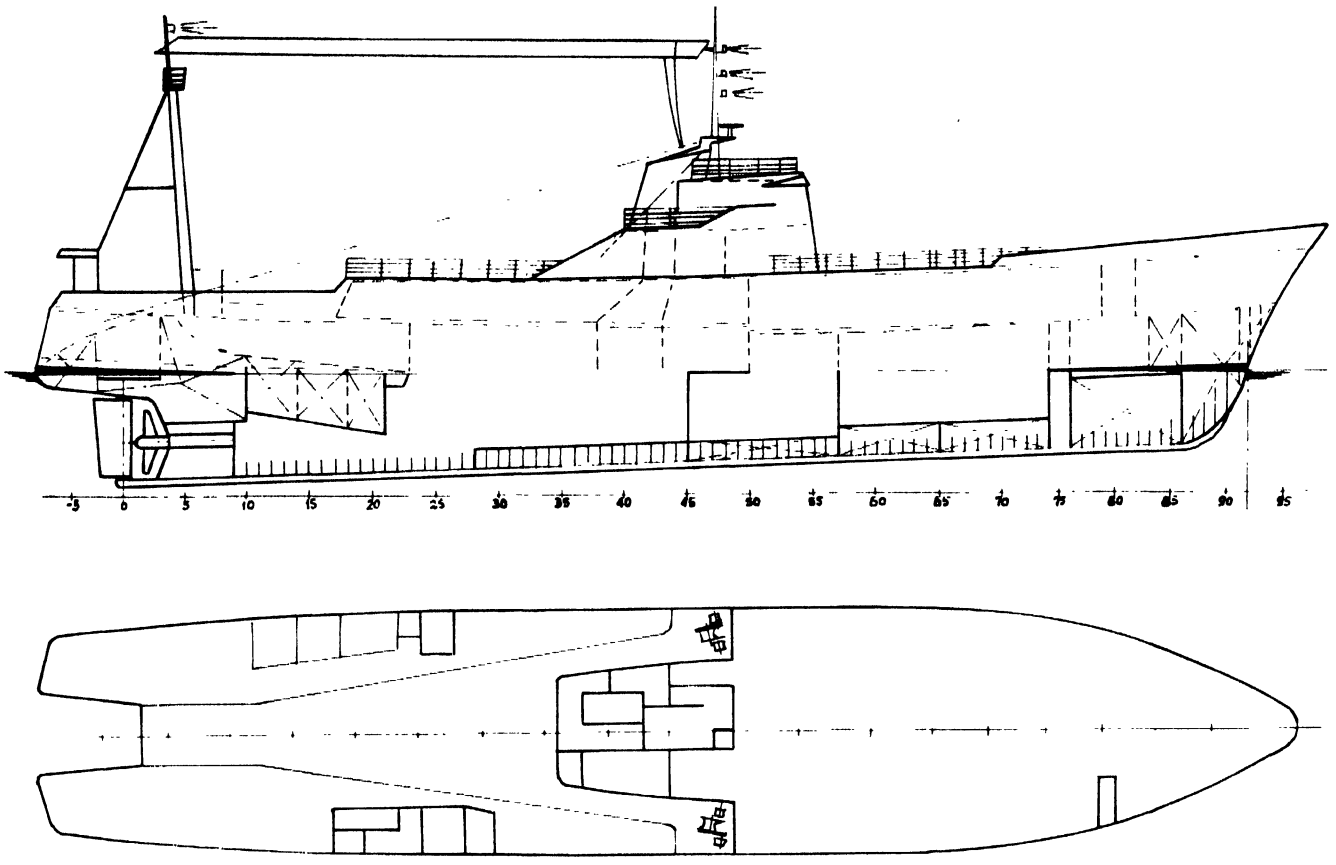

Fig 3. Stern trawler Type B411, with a middle fishing deck, one multi-drum trawl winch, two net hauling winches, superstructure and fishing-navigating wheelhouse located in the middle part of ship. The centre of the side wind pressure is near the centre of gravity

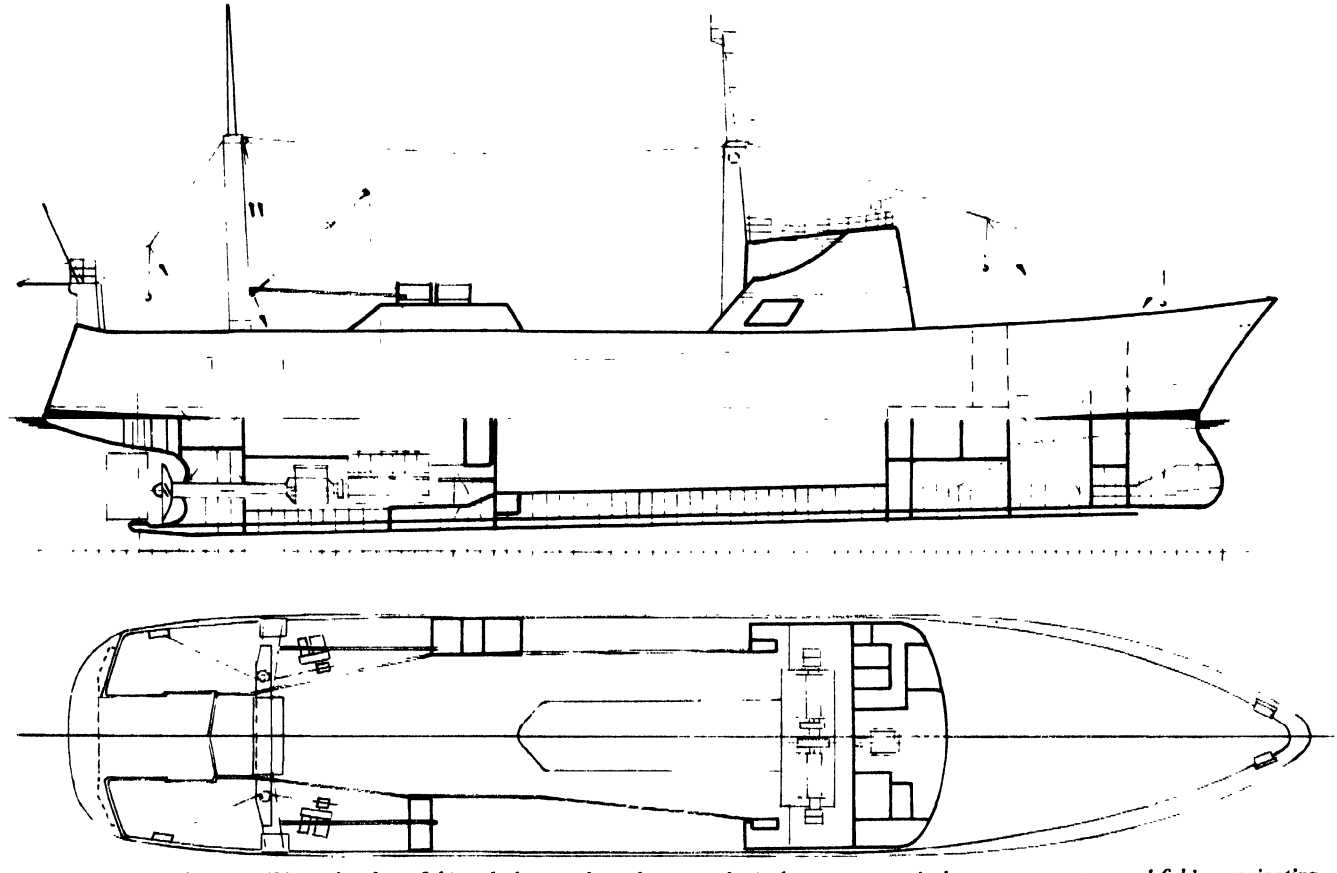

Fig 4. Stern trawler type 429, with a long fishing deck, one three-drum trawl winch, two cargo winches, superstructure and fishing-navigating wheelhouse located in the fore part of ship. The centre of the side wind pressure is near the centre of gravity moved to bow

navigation equipment and often leads to damage on those trawlers which have the wheel-house a long way forward.

Solutions of catching systems and fishing gear layout have so far mostly led towards extending the length of the working deck and the number of mechanical appliances, and to the wheel-house being situated increasingly further forward.

Some interesting constructional solutions, which illustrate developments over the past few years in the layout of fishing gear on stern trawlers, are given in this paper from Polish solutions.

Figures 1 to 4 illustrate chronologically the more interesting efforts in the design of stern trawlers.

CHOICE OF PROPULSION TO MEET WORLD TRAWLING TRENDS

Increasing the power of the main propulsion on stern trawlers, based on results and experience gained during operations does not always go hand in hand with the generally accepted principles for designing stern trawlers. On one hand, increased propulsion power permits fishing with larger trawls even in more difficult weather conditions and increases the free steaming speed; but on the other hand, greater power placed on ships of the same size forces the strengthening of the hull construction and gear and equipment foundations to guard against constructional damage and breakdown of equipment as the result of wave action and vibration. Increasing the main propulsion power and thus the ship's pull, and also the increase in the size of nets, means lengthening the working deck and the number and power of fishing deck equipment.

The aim of increased thrust is still not properly assessed by owners and designers from the economic point of view. There exist certain habits and customs and there is a lack of faith in solutions which enable much greater thrust to be achieved during trawling and even during free steaming by improvement of propulsion efficiency.

Most trawlers have direct propulsion. The revolutions of the propeller shaft are between 200–350 rpm and in these conditions there is no need to adopt controllable pitch propellers which make the system more expensive. Acceptance of that view makes it necessary to install a main engine with higher power and that means increased expense.

More consideration should be given to increasing thrust by lowering propeller revolutions and increasing propeller diameter at the same time. The larger propeller diameter dampens longitudinal pitching and also improves the ship's course stability, see Bennett *et al.*, 1968.

Without going into detail but based upon graphs from systematic experiments with Wageningen B-type model propellers and considering the propulsion system for two trawlers of 900 ton d.w. and 1,500 ton d.w. with the same type of main engine of 2,600 h.p. at 500 r.p.m. working controllable pitch propellers through reduction gears with respective ratios 1:2.86 and 1:4; the free steaming speed achieved was very similar and the bollard pull was about 27 per cent greater in favour of the larger trawler. Decreasing the propeller revolutions with the same pitch-to-propeller ratio and speed of advance gave increased propeller efficiency and thrust during trawling.

One of the difficulties in decreasing propeller revolutions and increasing diameter and thus increased stern draught is the draught restriction in shallow fishing ports. Even with a keel construction where the draught aft is greater than the mean draft, the ship can be trimmed so that it will be on an even keel when entering port.

INFLUENCE OF WIND ON SHIP STRUCTURE DURING TRAWLING

Extending the working deck usually means that the centre of pressure of the lateral wind force is moved forward, which means a lowering of course stability and increase in resistance resulting from the necessary rudder deflection. The value of resistance loss depends primarily on the hull shape in those parts which are above water and those submerged, see Dickson (1969).

Under the influence of a side wind forces acting on the hull superstructure, the ship's course will not be along ship's centreline but only at an angle to it. The ship will crab as shown in fig 5. The rectilinear movement of the vessel/trawl system will be decided on balancing the lateral components of forces acting on the hull and their moment in relation to the ship's centre of gravity G, which are shown as follows:

Balancing forces across centreline:

$$T_y - Y_W - Y_R + Y_H = 0$$

Balancing turning moments:

$$T_y l_T + Y_W l_W - Y_R l_R - Y_H l_H = 0$$

Balancing forces along centreline:

$$T_X + X_W + X_H + X_R - R = 0$$

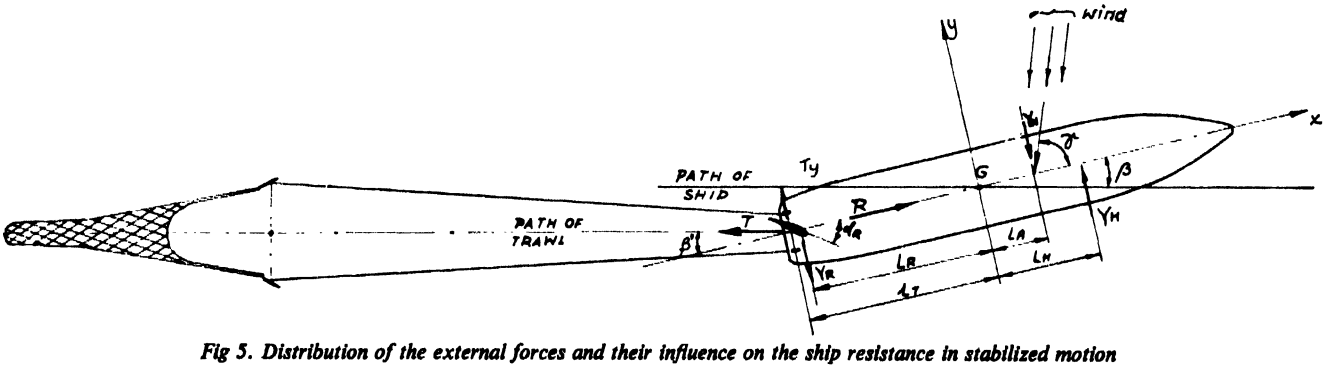

Fig 5. Distribution of the external forces and their influence on the ship resistance in stabilized motion

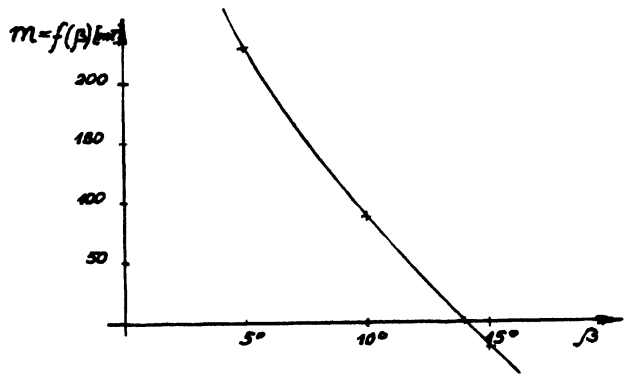

Fig 5a. Graphical solution to determine drift angle for given forces acting on the trawler

where:

T_Y, T_X = lateral and longitudinal components of force in warps

Y_W, X_W = aerodynamic force components from wind action

Y_R, X_R = lateral and longitudinal components of hydrodynamic force caused by rudder deflection

Y_H, X_H = lateral and longitudinal components of hydrodynamic force on the hull caused by ship's drift

R = propeller thrust

β = drift angle

β' = warp deflection angle

Without going deeply into the problem of ship steering, but considering the general principle for calculating the control of trawling and assuming that the ship is trawling at 4 knots and that there is a wind force of 7° B perpendicular to the ship's centreline then the aerodynamic force acting on the ship's exposed surface can be expressed as follows:

$$Y_W = \tfrac{1}{2}\rho_a C_{ya} V_{ap}^2 A_a$$

where:

ρ_a = air density amounting to 0.125 [Kg s^{2}m^{-4}]

A_a = projected area—view of exposed part of ship along its centreline

C_{ya} = coefficient of wind resistance

V_{ap} = speed of apparent wind which is what is measured

γ = angle of apparent wind.

There are some difficulties in determination of the wind resistance coefficient C_{ya} depending upon the angle of the apparent wind.

The hydrodynamic force acting on the submerged part of the hull, caused by the ship's drift, can be expressed by the formula:

$$Y_H = \tfrac{1}{2}\rho_W C_{yH} V^2 A_W$$

where

ρ_W = sea water density amounting to 104.5 [Kg s^2 m^{-4}]

C_{yH} = coefficient of lateral hydrodynamic force

V = ship's speed

A_W = projected area of the submerged part of the hull along the ship's centreline.

To determine the lateral hydrodynamic force acting on the submerged part of the hull, the most difficult problem is to calculate the lateral resistance coefficient C_{yH}, especially for the shape of the ship's frames.

During the design stage, to assess the influence of lateral hydrodynamic force on the steering of the ship, Milton's (1961), coefficients can be adopted, the relation of which is expressed in the equation for the given movement of the ship.

$$C_{yH} = C_{y1}\beta + C_{y3}\beta^2$$

where: C_{y1} and C_{y3} are Milton's coefficient.

After taking into account all corrections it is possible to calculate, as to the influence of the hull and propeller on the work of the rudder, the lateral hydrodynamic force on the rudder which can be expressed by the formula given by Basin (1949):

$$Y_R = \tfrac{1}{2}\rho_W \xi_1 C_{yR}(\alpha_R - \xi_2\beta) V^2 A_R$$

where:

C_{yR} = lateral coefficient of hydrodynamic force of the free rudder

A_R = rudder surface

ξ_1, ξ_2 = coefficients taking into account the influence of propeller and hull

α_R = rudder angle.

Of the wide range of problems which influence the dynamics of the trawling system in sea conditions only general considerations for rectilinear movement of the ship have been chosen with simplified assumptions:

1. wind force and direction are constant in all planes parallel to the water plane;
2. forces and moments from sea waves caused by wind are not taken into account;
3. rolling and pitching of the ship due to the action of wind are not taken into account.

In balancing the trawling system forces in the warps, the hydrodynamic and aerodynamic forces acting on the ship are given not chosen and therefore the balancing of forces to maintain rectilinear movement of the trawling system is only possible within limits by deflecting the rudder and causing transverse hydrodynamic force on the rudder.

Data from a stern trawler serve as an example. Using the equations given and taking into account certain corrections, the transverse aerodynamic force from a wind of 7°B acting perpendicular to the ship's side amounts to:

$$Y_W = \tfrac{1}{2}\rho_a C_{ya} V_{ap}^2 A_a = \tfrac{1}{2}0.125 \cdot 1.16(15.15)^2 440 = 7.5 \text{ ton}$$

and is applied to the centre of the wind pressure at a distance of $l_W = 5$ m from the ship's centre gravity G.

The transverse hydrodynamic force caused by the ship's drift amounts to:

$$Y_H = \tfrac{1}{2}\rho_W(C_{y1}\beta + C_{y3}\beta^2) V^2 A_W = 62.8(C_{y1}\beta + C_{y3}\beta^2)$$

and is applied at the distance of $l_H = 25$ m from the ship's centre of gravity.

Warp force when the rollers on the stern gantry are placed symmetrically, amounts to 12.5 tons and the

transverse component is at a distance of $l_T = 34$ m from the ship's centre of gravity.

The transverse hydrodynamic rudder force is at a distance of $l_R = 32$ m from the ship's centre of gravity. After substituting, balancing the remaining forces take the following form:

$$Y_R = \tfrac{1}{2}\rho_w \xi_1 C_{yR}(\alpha_R - \xi_2\beta)V^2 A_R = 8.8\, C_{yR}(\alpha_R - 0.28\beta)$$

Introducing values into the forces and moments equations, we obtain an equation in which the drift angle is a variable. Assuming several values for β and choosing an effective rudder angle α_R, and so therefore and C_{yR}—the open water rudder transverse force coefficient is determined, then the easiest solution is the graphical method as shown in fig 5a.

In this case the solution is that the rudder should be at $\alpha_R = 25°$, and ship should be put on a drift angle $\beta = 14°$ to maintain a straight course in a crosswind of 7°B. Due to the drift angle and the shipping crabwise the component of water resistance along the centreline is greater than the expected hulldrag added to which there is the rudder drag. All these factors mean about 15 to 20% of the total ship's resistance during trawling. This increase of resistance must influence in a negative way the size of the trawl which can be operated at a chosen trawling speed.

Describing this problem by calculation it is intended to highlight some details of ship construction and layout which have a considerable effect on the ability of a stern trawler to fish. These factors are particularly propeller size, vessel draught and shape of above water hull. It is also proposed to show some design solutions which may influence the operational characteristics of stern trawlers.

SELECTION OF FISHING SYSTEM AND FISHING DECK MACHINERY

The side trawlers were gradually perfected in line body, shape, fishing system, fishing deck machinery until a practically final form was reached. For stern trawlers the selection of the line body form, fishing system, fishing deck machinery, compartmentation of the ship space and propulsion systems is open and many greatly different solutions have been tried, all dependent on the owners' experience and designers' practice.

For shortening the operations with the trawl on the deck, i.e. hauling, emptying the codend, repairing and shooting out of the trawl net it could be possible to use a two-trawl net system. Such a system requires extended working deck.

Working by this method it is possible to save about 20 minutes on each haul, i.e. one additional haul per day. Such a method would require two separate one-drum trawl winches and a multi-drum net haul winch as shown in fig 6.

From the rhythmical point of view, the two-trawl net system has attractions and possibilities. Figure 7 shows how navigating and fishing control can be commanded from one station.

A further point shown in fig 7 is the ability to move the trawl sheaves on the stern gantry independently. Calculations show that considerable advantage is to be gained in balancing the forces acting on the trawler when she is fishing by moving both sheaves to the windward side. This in fact is a very common practice for maintaining steerage way when towing fishing gear on small vessels. There is no practical doubt about its efficacy, the more difficult problem is that of the forces

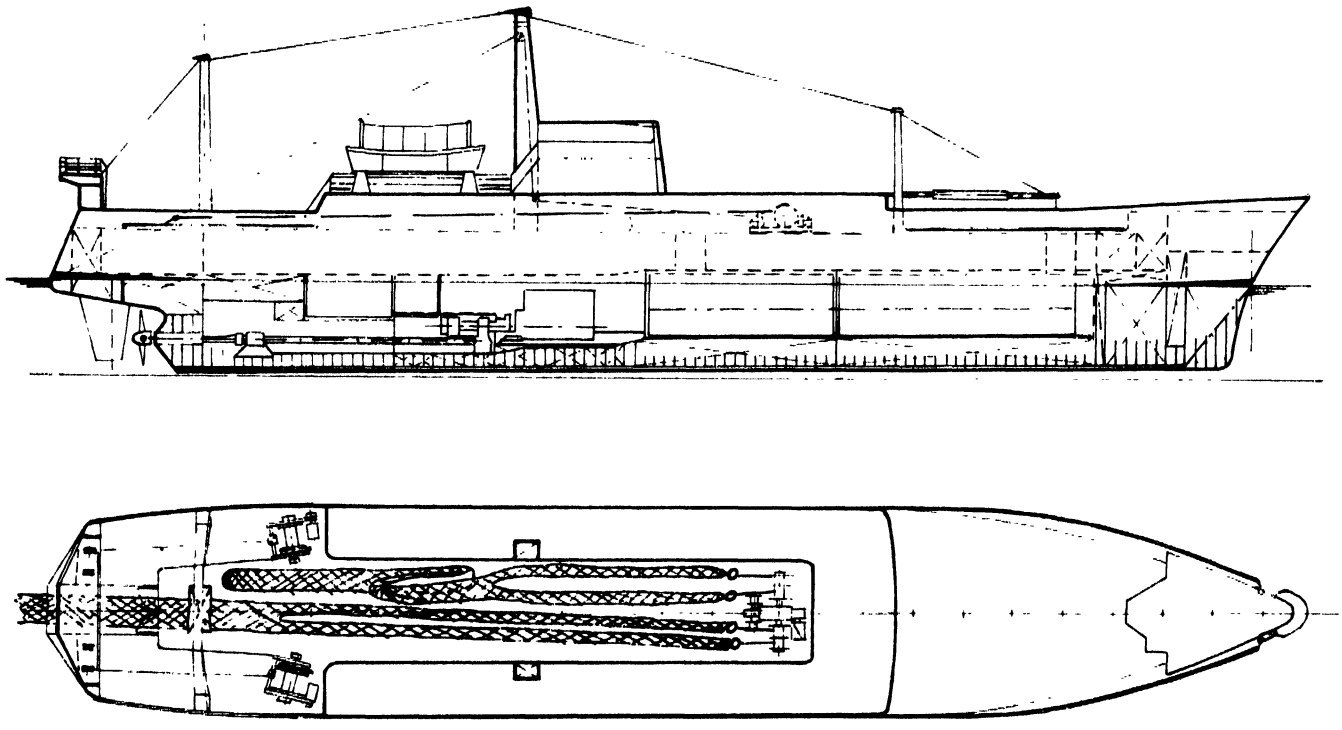

Fig 6. Stern trawler with a long fishing deck, two single-drum trawl winches and one multi-drum net hauling winch—foreseen for two-trawl operation. Superstructure and fishing-navigating wheelhouse located in the middle part of ship. The centre of the side wind pressure has moved to aft from the centre of gravity

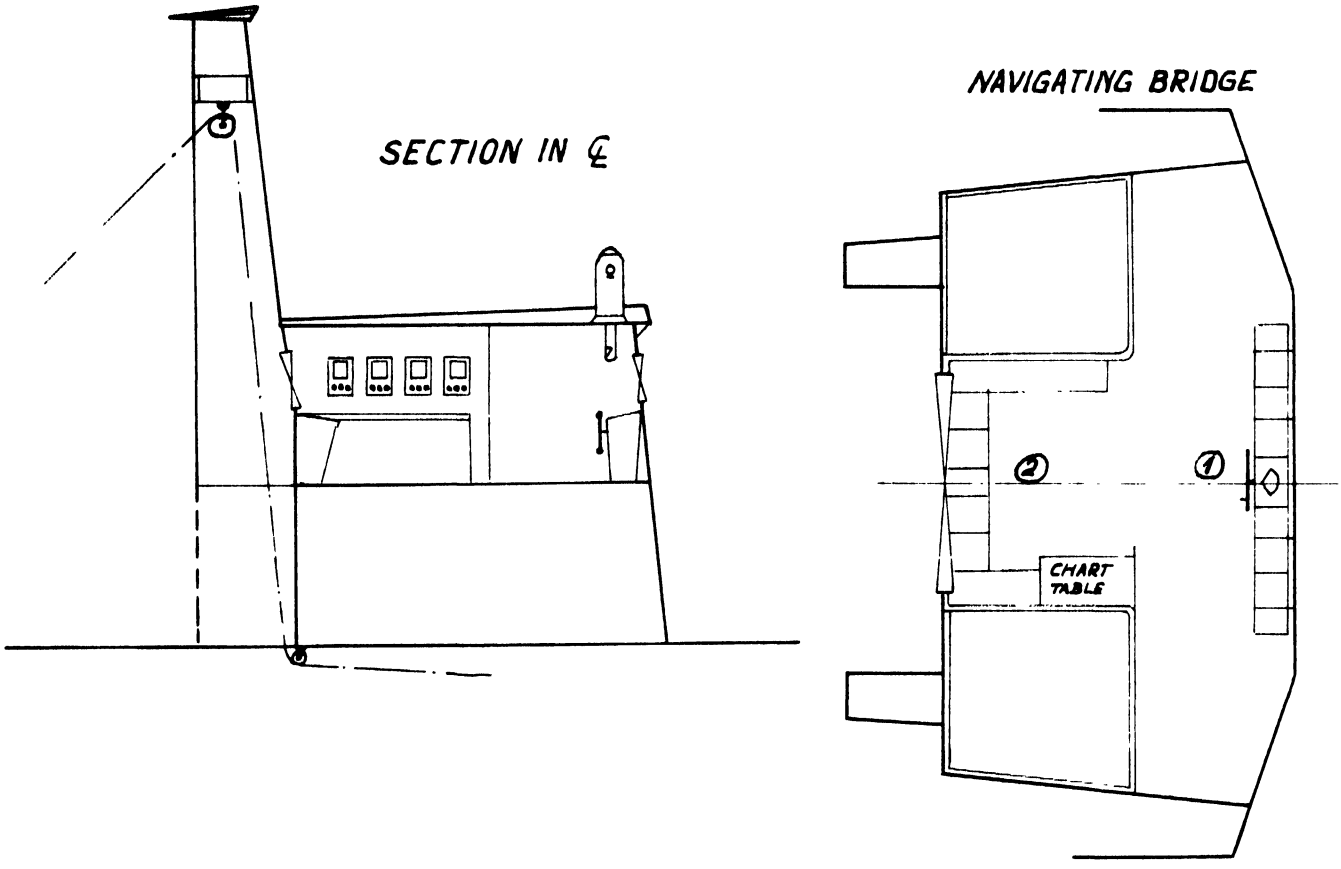

Fig 7. Navigating and fishing wheelhouse.
(1) Navigating equipment unit consisting of steering wheel with autopilot, gyrocompass, engine room telegraph, remote C.P.P. radars, etc.
(2) Fishing equipment unit consisting of trawl winch remote control console (R.C.C.) net hauling winch R.C.C., remote C.P.P., netsonde cable winch R.C.C., hydroacoustic equipment, master communicator, etc.

and arrangements involved in shifting the sheaves on large vessels.

Conclusions

1. More attention needs to be given to the towing characteristics of large stern trawlers;
2. Steering characteristics of large stern trawlers while towing are generally bad and more consideration is required of the forces acting on the trawler while towing in bad weather conditions.
3. Some thought is being given to means of reducing windage and bringing its centre of pressure further aft in order to improve steering while fishing.
4. Means of offsetting the warps to the windward side are being considered as a means of improving steerage way while fishing.

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Trawl Gear Selection, Design and Construction in Relation to Fish Behaviour, Vessel Power and Fishing Conditions

W. Dickson

Choix, conception et fabrication d'engins de chalutage en fonction du comportement du poisson, de la puissance du navire et des conditions de pêche

Avant d'aborder l'examen des aspects techniques de la conception des chaluts, le présent document insiste sur l'utilité d'une étude de la documentation relative à la pêche et aux poissons visés. Il existe différents degrés dans la conception des chaluts, depuis le choix de plans sur catalogue jusqu'à l'apport de simples modifications à des plans complets et aux tentatives d'optimisation. L'auteur décrit un processus de répétition commençant par l'établissement de conditions limites auxquelles doit se conformer l'élaboration des plans d'un chalut destiné à un certain chalutier. Il prend comme base de départ un filet standard de type et de dimensions comnues, compte tenu des conditions limites susmentionnées; ce filet sera modifié à plusieurs reprises à mesure que l'on examinera les conditions qui prévalent sur le fond, les espèces ichtyologiques en cause et leur comportement. Se document mentionne les diverses sources auxquelles il faut se reporter pour l'élaboration des plans. Un chapitre traite brièvement des évaluations de l'abondance du poisson par le chalutage et par les méthodes acoustiques, désormais à peu près normalisées, afin de parvenir à une meilleure appréciation de l'efficacité des essais de chalut. L'auteur envisage l'optimisation des plans sur la base d'expériences de pêche comparées, telles celles effectuées depuis de nombreuses années, et de la possibilité croissante de recueillir et de traiter des données provenant d'une flotte de pêche, à condition de s'appayer sur un minimum de plans acceptables de recherche opérationnelle.

Selección, diseño y construcción de artes de pesca al arrastre en relación con el comportamiento de los peces, la potencia de las embarcaciones y las condiciones para la pesca

Antes de empezar a ocuparse de los aspectos relacionasos con la igenieria del diseño de los artes de arrastre comiensa poniendo de relieve el valor de un estudio de los trabajos basicos publicados sobre la pesqueria y los peces de que se trate. Existen diferentes niveles del diseño de los artes de arrastre que van desde la selección en catálogo hasta las sencillas modificaciones para completar el diseño y los intentos para mejorarlos todo lo posible. Se describe un proceso de repetición en el que se empieza por establecer las condiciones límites a las que debe atenerse el diseño de un arte de arrastre para un pesquero dado. Sequidamente se adopta como el punto de partida del diseño una red normal de diseño conocidos y dimensiones de trabajo y que cumpla aquellas condiciones, límites la cual se modifica una y otra vez a medida que se atiende a las consideraciones de las condiciones del fondo, especies de peces y su comportamiento. Una sección se ocupa brevemente de la estimación de la abundancia de peces por medio de un arte de arrastre y por medio de los que métodos acústicos que actualmente son bastante normales, con objeto de determinar mejor la eficiencia del muestreo con artes de arrastre. Se estudia el máximo mejoramiento del diseño del arte de arrastre desde el punto de vista de los experimentos de pesca comparativa, como los que se han estado realizando durante muchos años y de la posibilidad en desarrollo de recoger y elaborar los datos de una flota, dado un mínimo aceptable de planificación de las investigaciones operativas.

THE designing of a trawl is deceptively simple; like other nets it has been defined as a series of holes joined together by twine. The temptation to experiment is almost irresistible: the difficulties come in determining meaningful objectives.

This review deals only with bottom trawls, except in so far as dealing with where and when to use the bottom trawl may be related to considering the use of other gears.

Search the background literature

FAO is always interested to know of new fishing ventures in developing countries. The Biological Data Section can dig out reference material pertaining to any particular area and The Fishing Gear and Methods Branch can help with knowledge of fishing methods used or likely in most developing areas.

Before contemplating the selection or design of a new trawl, it is vital to make a review of what literature is available on the fishes, with emphasis on what is known of their behaviour and on the fishing methods applicable. Also visit local harbours and fish markets and discuss their fishery with local fishermen.

Some general reviews have been made. Helpful in understanding the behaviour of the various important gadoid species is Saetersdal's review (1969). He emphasizes the importance of what can be learned from a good echo sounder survey in the way of distribution densities and vertical diurnal migrations, all of which is necessary background information for correct selection and design of trawling gear.

As enough data on each important species become available, FAO Resources Division bring out new issues of their Synopses of Fisheries Biological Data. This series deals with life history, distribution, abundance, reproduction, behaviour characteristics as well as with more purely scientific considerations.

An approach to the collection of background information on a particular fishery from a developing country and the subsequent design procedure for a trawl for a given trawler is given by Dickson (1968).

From the background material a summary should be written and conclusions about design parameters should be drawn. A look at the iterative process described in fig 1 will show the kind of questions to which answers should be sought.

DIFFERENT LEVELS OF PROCEEDING WITH SELECTION AND DESIGN

There are several ways of approaching the problem depending on the designer's sophistication and time available. Simplest is to look through catalogues and select whatever looks suitable. The next is to select and modify, which is deceptively simple and full of pitfalls. Real design work may either start from a concept of a new design or more usually the process is to select, modify, and redesign.

A number of catalogues can be used for selection. The FAO Catalogue of Fishing Gear Design (1965) gives

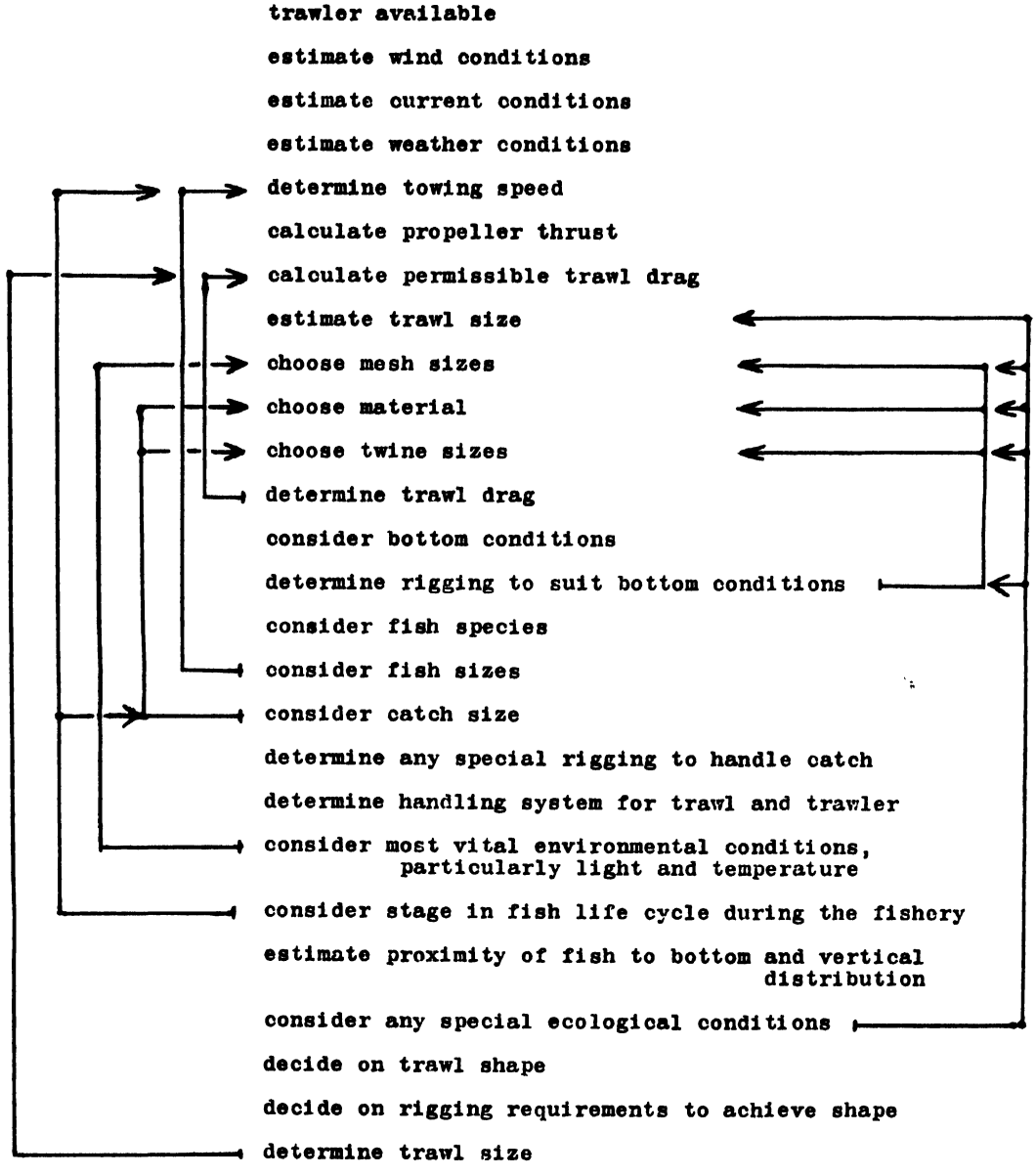

Fig 1. Reiteration process in trawl design

a variety of trawls for different purposes and for different sizes of vessel. Another source of trawl designs and rigs is Nédélec and Libert (1964) also covering trawls suitable for a range of vessel sizes. A catalogue of shrimp trawl designs has been produced by Kristjonsson (1967). It is also a review of shrimp catching methods.

It can happen that no design would quite fit the vessel available, the species, size, ground conditions, etc. Often it would be desired to make the trawl in synthetic twine and not natural fibre but it is by no means necessarily the best way to replace natural fibre twine with synthetic twine of the same diameter though that is the simplest modification.

Select and modify

If twine diameter can be reduced by the use of synthetic twine then the options are to reduce otter board area pro-rata and thus let the gear be towed a little faster, or keep the otter boards the same and make the net a little bigger. If the mesh size in the mouth of the trawl design selected is not considered quite right, there is no problem in increasing the mesh size and twine diameter pro-rata because this makes a stronger net. Conversely, reducing mesh size and twine diameter pro-rata makes a weaker net, so that either only a small reduction in mesh size is acceptable or else twine diameter has to be reduced less than mesh size, in which case the otter board area should be increased or the net made slightly smaller, for otherwise the fishing shape of the trawl will be different from that in the selected design. Remember!—that design was selected because it was known to give satisfactory fishing dimensions with the selected otter boards; "experiment" with these fishing dimensions and the chances are the gear may no longer work satisfactorily.

Simple modification can be done as follows. First, the drag of a net depends largely on net size or area so there

is an area factor to be manipulated. Secondly, there is a mesh size factor to be dealt with and clearly the bigger the mesh the smaller the drag. Thirdly, there is a twine factor which depends on twine diameter. Lastly, there is a towing speed factor.

A simple scaling equation embodying these factors can be built up as follows:

$$\frac{D_m}{D} = \left(\frac{M_m N_m}{M N}\right)^2 \times \left(\frac{M}{M_m}\right) \times \left(\frac{\rho R}{\rho_m R_m}\right)^{\frac{1}{2}} \times \left(\frac{v_m}{v}\right)^2 \quad (1)$$

Drag Ratio	Area Factor	Mesh Factor	Twine Factor	Speed Factor

where: D = standard drag

M = standard mesh size

N = standard number of meshes round the mouth

ρ = standard specific gravity of twine

R = standard runnage of twine

v = standard towing speed

subscript "m" denotes the modified set of conditions.

There are limitations to using this formula. It applies only to nets of the same shape, i.e. to bigger or smaller versions of the same net, and it applies even then only when the bigger or smaller version is spread to the same proportion of the headline length and height or more strictly when the fishing shape is the same. The formula only compares one set-up with another: therefore, somewhere along the scale conditions must be known. It also assumes that the drag of sheet netting is proportional to the square of velocity. The drag of a whole trawl does not even approximately vary with the square of the velocity because its shape and so also its resistance changes with the velocity. Another error arises if the open area ratio of the meshes is much reduced for then the water flow through the net is reduced, blockage occurs and the change of drag becomes indeterminable by calculation. Even if limited in application the formula has shown itself quite good enough for tackling many scaling problems: nets scaled according to the formula behave in a reasonably predictable way.

Correct square length

If modifications are not correct, the gear will be either overspread or underspread. If overspread, the square will be unduly stretched laterally and unduly shortened with respect to the overhang between headline and groundrope and so liable to burst, particularly at the quarters. Top of the net will be unduly tight and the headline ridden down. If underspread, the meshes round the mouth of the net will be unduly elongated, their open area ratio will be bad, the square will be unduly long for the overhang between headline and groundrope and this slack in the top half of the trawl may cause a pocket in the net in front of the codend.

REITERATION PROCESS IN SELECTING OR DESIGNING

It will usually be the case that a trawl has to be selected or chosen for a certain vessel or class of vessel and the trawler available may therefore be taken as the starting point.

The first logical steps are with the engineering problem of setting the boundaries of drag and speed within which the gear must fall. Wind, current and weather conditions have to be considered. The worse these are, the more propeller thrust is required to drive the vessel and the less is available for the trawl. In some fisheries the maintenance of steerage way is more important than in others, particularly when working edges, contour towing.

It is also true that the drag of a trawl rises somewhat more than the first power of the speed. Thus the penalties paid for increase of towing speed are heavy and the greatest volume of water will be filtered or the greatest area covered by towing as big a trawl as possible, as slowly as possible, while still utilizing the maximum available thrust. The thrust available from the propeller can be estimated from curves derived by van Lammeren *et al* (1948). Some refinements for trawlers in the towing condition using three different types of trawls are given by the White Fish Authority (1968). The wake fraction and thrust deduction factors are worked out for these typical cases. Drawing the lines of trawl resistance across these available thrust curves as shown by Freedman (1967) or Dickson (1966) sets the limits to the towing conditions at which trawls of different drag characteristics can be operated. A simplified diagram is shown in fig 2.

Choose a standard

A net of known design, operating dimensions and drag may then be taken as a standard to work from. Carrothers (1969) gives a series of standards. Another standard for the Granton trawl is given by Dickson (1964). Every net designer naturally keeps his own records of the relationship between fishing dimensions, towing speeds and tensions in the various parts of the trawl gear he has investigated and uses these as his own standards. Sooner or later a collection of these individual standards will have to be put together in a generally standardized form, perhaps by FAO. At the first Fishing Gear Congress there was a call for collecting such data; at the second it was reported that considerable data had been collected; now it is possible to talk of putting it into standard form.

There are various formulae available to give the drag of a trawl in terms of overall size, its mesh sizes and twine sizes, its operating dimensions and speed of towing. All of these are derived from specific cases and contain coefficients such that application of the formulae to nets of radically different shape and open area ratio of meshes becomes risky.

The best way remains to scale up or down from known standards with broadly the same shape and characteristics. A better way still when estimating the drag of a new design, is to bracket by scaling up from one standard and down from another.

Start designing from the net end, from what are thought to be suitable overall size operating dimensions, mesh size, twine size and towing speed; calculate drag and from the sweep angles determined by the operating dimensions of the net work back to what spreading force is required from the otter board; hence derive their size and consequent drag. Usual references on otter board performance are Yakovlev (1955), Arlotte (1964), Dale

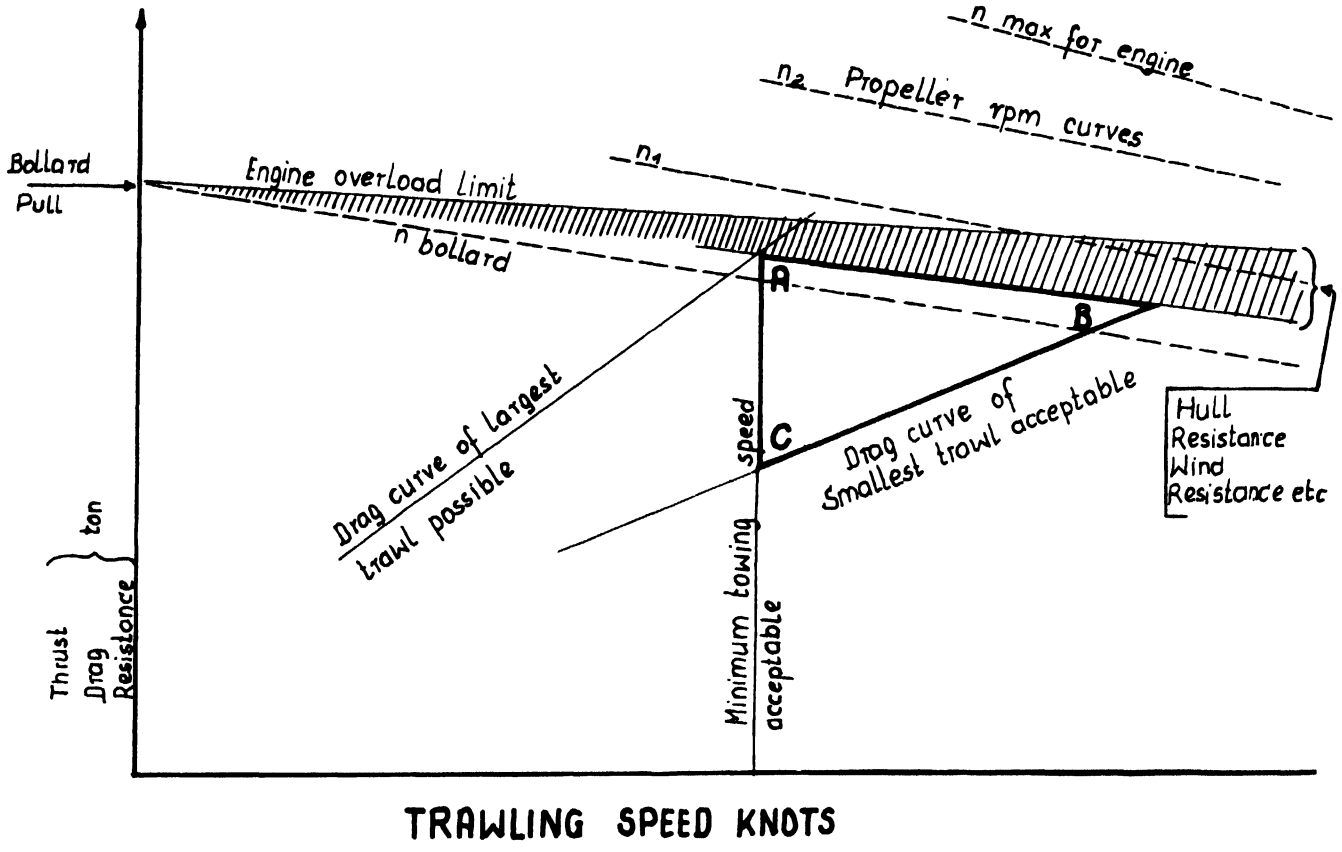

Fig 2. Boundary conditions for trawl design

and Moller (1964). From there work back to the ship, adding on the warp drag and compare the total drag of the gear with the available thrust; work round the loop again as necessary.

Trawl models

Large scale trawl models towed by a motorboat can be useful in trawl design—particularly to adjust cutting and tailoring of net shape to eliminate defects and quickly test the effect of variants in wire rigging. The method requires frogman technique and model making technique. The theory of this kind of modelling is given by Dickson (1961 and 1966). It has been used by Schärfe (1966). Freedman (1969) describes an alternative method when large models have been towed below a catamaran pulled by a winch along a canal, but he also uses motorboats on a lake. All users of modelling would agree that it may be an auxiliary to, but never a substitute for, measurements on operating dimensions of full scale gear.

Only a certain range of twine sizes will be acceptable for a given size and power of trawler and these depend upon material chosen and mesh size. The ground also has to be considered. For rough ground it is better to have material of specific gravity less than unity, polyethylene or polypropylene, to keep the netting floaty or, alternatively, make the net in nylon with its good properties of sustaining shock loads. For lightweight nets nylon is better because it allows smaller twine diameter for equivalent strength and so allows biggest nets to be made for equivalent drag. Cost, and its generally good properties, keep polyethylene material in the running, especially for hard duty.

For groundrope rigging details refer to Nédélec and Libert (1964). A point made by several net designers is that on rough ground it pays to design a net with at least some 3 m of headline height though the figure is to some extent dependent on net size, thus keeping the belly and codend clear of the bottom.

Not more than enough headline height

Design nearly always means compromise and against desirability of keeping netting clear of the bottom is another factor. The greater the headline height the greater the rise slope of the netting in the belly and the greater the component of force tending to lift the groundrope. Thus, as shown in the sketch, the groundrope of a high headline net will not follow small uneven contours in the bottom—unless it is considerably heavier than normal. A similar argument applies for the upward component of force on the groundrope due to water pressure on lower wings (fig 3).

This is one reason why fishing performance of high headline nets has so often been disappointing. Before this problem was fully appreciated one net the author had designed for an 800 t trawler to fish with a headline height of 5 m, though the rubber bobbin groundrope appeared to be in good bottom contact at that height, still would not, in normal North Sea haddock fishing conditions, fish at all well until floatation was reduced so that the net came down to 3 m headline height.

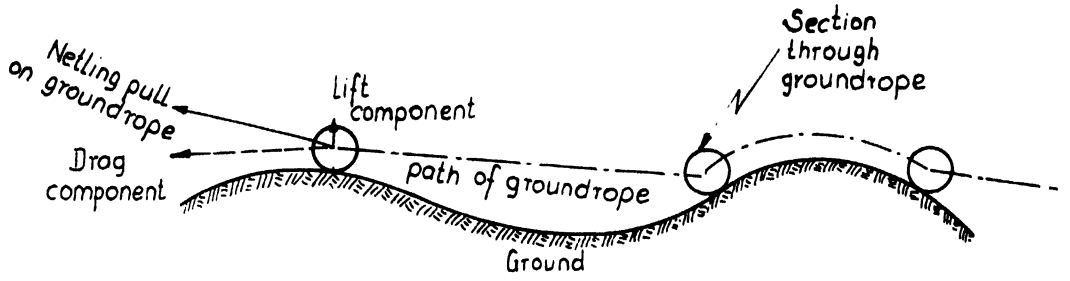

Fig 3. Illustrating how the groundrope of a high headline trawl may skip the ground

Writing of similar sized ships, Foster (1969) has given the view that at all speeds the ground reaction on groundrope should be not less than 270 to 320 kg and that for a high headline trawl this figure should be increased by a factor of two.

Slack in lower net

Rough ground trawls often have considerable slack set into lower wings and belly. Slack means the stretched length of lower wings and belly is greater than the stretched length of top wings, square and baitings. It may be that the slacker netting puts less constraint on the descent of the groundrope following its rise over an obstacle. Perhaps also slacker netting allows more local distortion of the groundrope as it is restrained by obstacles thus causing less excess localized stress and fewer netting bursts. It seems likely that in lightweight nets many bursts are due to stresses arising in the netting from rapid changes of shape in the curve of the groundrope rather than through direct snagging of netting on the bottom. This slack in the lower net does throw the balance of tension rather more on to the more taut top half of the net and therefore is a feature which reduces headline height below what it would be if no slack were allowed. Whether to allow slack in the lower net, and, if so, how much, depends on what kind of fishing the net is designed for.

The nature of the bottom also affects the wire rigging and otter boards. On roughest trawling grounds no more than 30 m sweep wires will be acceptable; on smoothest, 200 m sweeps are possible. If double sweeps are used the net drag is divided between them; consequently, the lower ones sag more than would single sweep wires. Double sweeps on rough ground must consequently be shorter than single sweeps. It is hardly practical to make double sweeps longer than 50 m on anything but good ground.

On soft ground, such as in deep Mediterranean water, and in many tropical areas, otter boards may require broader keels or mud shoes and a front shape causing them to ride out of mud. An otter board can have 25 per cent sheering force provided by groundsheer by the nature of the ground. An attempt to take extra advantage of this ground sheer by increasing the weight of the otter boards led to their sinking into mud in areas where it was soft. Normally, ground reaction on the otter board should be some one-third of its weight in water (Crewe, 1962). In very deep water the practice in northwest America is to use heavy otter boards and a shorter warp/depth ratio. In five volumes of tables Crewe and Arlotte (1962) developed a theory for determining required warp/depth ratio or scope and also warp drag.

Fish species requirements

The species to be caught and their sizes affect design. Likely vertical distribution near the seabed and their proximity to the seabed affect net shape. These requirements may be deduced by experience and may be considered more theoretically (Alverson, 1969) if the rate at which the fish density changes near the seabed can be determined.

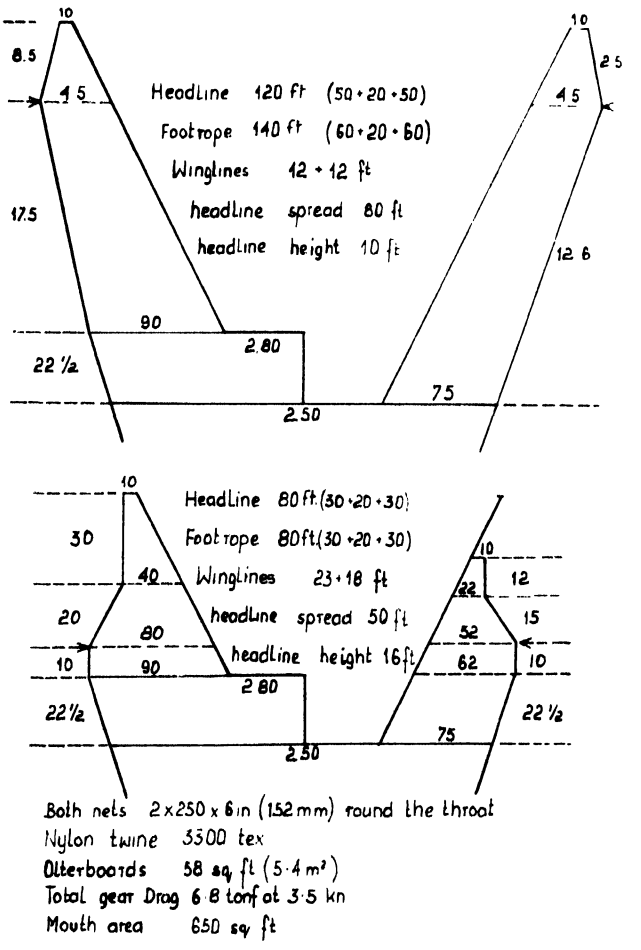

Fig 4. Schematic example for changing the shape of the trawl mouth by modifying the wing design

The trawl shape to some extent effects drag and calls for special rigging features. In fig 4, for instance, for the same basic size of net round the throat two different wing shapes have been used. The longer wing version gave a moderate headline height of 3 m with 30 m spreading wires plus 30 m sweeps. In the stump wing version, the whole emphasis was on achieving a headline height of 5 m with 50 m double sweeps. The drag of the nets was almost the same: in one case being more due to the wings, and in the other, more due to the bag. Note how headline height can be achieved by cutting bits out of a net instead of sewing in extra side panels.

The size of catch if likely to be big, will call for special rigging features and requirements in material and twine size in after parts of the net; also for special handling tackle.

Fish size and mesh size

Fish size has an obvious influence on mesh size in the after parts of the trawl and codend particularly, but the relationship is not solely dependent on fish size. Herring, for instance, because the fish is soft, is less damaged by a small mesh codend. In forward parts there may be a connection between animal size and mesh size as for trawls to capture Norway lobsters, *Nehrops norvegicus*, and most shrimp trawls but often no obvious relationship exists. Sprat trawls in the Baltic and trawls for industrial fishing for the small *Gadus esmarkii* or the sandeel *Ammodytes* in the North Sea have a larger mesh size in the forward parts than do cod trawls in the Arctic. If generalizations can be risked, they might be these:

(i) A bigger mesh size in forward parts of trawls can be used for fish which school as distinct from those which merely aggregate;

(ii) The less light there is the nearer mesh size should approach that through which fish cannot escape;

(iii) Optimum mesh sizes in forward parts are somewhat dependent upon the size and taper of the trawl, as now discussed.

From observations made from a bathyplane, Martyshevskii and Korotkov (1967) concluded that there were four rather distinct areas for different fish reactions to the trawl in daylight. The first area extends from otter boards to wing tips. The second lies between wing tips and back part of the belly. The fish thus observed on West African grounds in general made few attempts to escape through meshes of this area unless the netting actually touched the tail in which case it was tripped in its swimming and passed out through the large meshes. In general, fish in this area seek for a big opening and finding none pass back into the bag. The third area includes the last part of the belly and the conic section of the trawl bag. In this critical area fish become concentrated, rush about and seek escape through the meshes. Fourth area is the codend. In free diving operations during daylight Hemmings (1967) reports how haddock in the mouth of a danish seine kept distance from each other and sought to avoid overcrowding.

The critical area in which fish, when there is a concentration of them, panic and seek escape through the meshes is thus relatively further forward in the net when the nets are smaller or more rapidly tapered. The suggestion, therefore, is that small and rapidly tapered nets should change from large mesh to smaller mesh relatively further forward.

Herring trawls are more gradually tapered and tend to be bigger but in a badly designed one, the herring become meshed in the bag. The net has then to be redesigned to bring the small mesh ahead of the critical area and perhaps also to make a big step in mesh size from one through which the fish can pass without meshing to one through which they cannot pass. It is, of course, bad if such a step is made too far back in the net.

A point for research workers who wish to sample by trawl the young fish in the year class or classes before they enter the fishery (something fishermen do not or should not wish to do) is that putting a small mesh cover on the codend gives a sample, but it is quantitatively likely to be a rather different one from what it would be if the net were specifically designed to capture small fish by bringing the small mesh forward into the tapered part of the bag and changing the mesh sizes in a different series of steps.

At each of these steps there will be a bigger outflow of water through the larger mesh than the smaller and the net may bulge at the join. Ideally, therefore, the twine diameters should be changed pro-rata with the change in mesh size at these joins. This is rarely a practical possibility on two counts: first, because the loss of twine strength dependent not on diameter but on area of cross section would be too great, and secondly because when mending a net it is a nuisance to have too many different twine sizes (thus rough ground nets have the fewest different twine sizes and maybe only one twine size). For the similar reason of avoiding pockets at a change of mesh size the stretched width of adjoining panels should be the same. This is not always so easy to arrange either because the take-up or joining ratio of the meshes should be kept to a simple fraction—obvious to men who have to mend nets.

Scharfe (1959) reported that North Sea trawls with wide open meshes in the wings are quite ineffective in Mediterranean fishing compared with long winged Mediterranean style of trawl which has wing meshes set very closely together. The high opening style of net with the forked wing ends of the Swedish herring trawl style has been reported as effective in the Mediterranean by Maurin (1965) for sardine and anchovy trawling at certain seasons when they are near the bottom, but with smaller meshes in the wings and square than used in North Sea herring trawls. Furthermore, this style of net was reported as being less effective than the ordinary flat long winged type of Mediterranean trawl in deep water for other species and much of the best trawling in the Mediterranean is in very deep water.

In the North Sea, Dickson (1969) found that in daylight a net where a smaller sized mesh (89 mm) was carried forward into the bunts of the lower wings, the belly, square and baitings caught more haddock and whiting than one with the 140 mm mesh carried back into the first part of the belly and baitings even though the smaller mesh meant a loss of 27 per cent mouth area.

The larger meshed net was the better for flatfish. Both nets were rather small.

In the 1930's the Granton trawlmen followed by those of Aberdeen started to use trawls with about 89 mm mesh size in the square and baitings rather than 140 mm. Parrish (1951) confirmed by comparative fishing experiments that the Aberdeen trawl so constructed was better for haddock and the Lowestoft trawl with the larger mesh in square and baitings was better for flatfish, though these mesh sizes were not the only difference between trawls.

Herring trawls as distinct from haddock and whiting trawls have a mesh of 140 mm to 200 mm in the square. There are some escapes through these meshes as described by Zjilstra (1967) but presumably not enough to warrant the reduction of mouth area of the net that a smaller mesh size would entail. This kind of experiment where small mesh collecting bags are sewn onto various parts of the net is indicative only. The small mesh collecting bag may either cause a blockage and a reduction of escapes through the area being investigated or the drag of the small mesh bag may cause pocketing of the main net and localized increase of escapes.

Much work remains to be done on these aspects of how species and size selection is dependent upon choice of mesh size in the forward parts of the trawl. From the harvesting point of view there can be little doubt that it is more important than the quite considerable effort that is devoted to codend mesh size experiments. Fortunately, this is one field of work where it is possible to carry on both kinds of experiment at once.

Some odd factors

These are the hardest to foresee and most often can only be learned by experience on the grounds concerned. Often the considerations arise from other factors in the ecology not directly related to species being sought. For instance, the presence of duffs (large, heavy silicose sponges of whitish colour) in quantity demands special wire rigging of the groundrope bobbins with spaces between them and longer grommets or chains between bobbin groundrope and net footrope. Also by lengthening the groundrope slightly to the same length as the net footrope, they will ride above the groundrope rather than behind it. The Queen trap where the meshes in the forward part of the belly behind the bosom of the groundrope are much enlarged to allow large shells to pass through is another example.

Fishing on the Wadge Bank off South India, Okonski (1969) has reported that polyethylene twine was operationally better than nylon because of the abundance of sea fans, gorgonids, on the bottom. The slippery polyethylene nets not only picked up less of these sea fans but were more easily cleaned from what they did pick up.

During southwest monsoon there is a big influx of various migrant species of carangids on to these grounds and a high opening lightweight net would then appear ideal, except that the resident species include the odd fair-sized shark and big sawfish in every haul and these could swim through a lightweight net as if it were not there. They occasionally did, even nets not lightweight.

Furthermore, a big sawfish with its saw stuck through codend meshes, could cut it right open.

ECHO SOUNDERS AS GUIDES TO ABUNDANCE

This section will be kept very short. Nevertheless, use of echo sounders is related to where and when to use bottom trawls, and their selection and design.

However useful the sounder, it is only a guide. With echo integrators or echo counters attached to echo sounders and with narrow echo beams stabilized in one way or another, the relationship between echo counts and fish catch is becoming better. In a graph given by Dowd (1969) the relationship may be out by about three either way, meaning the catch may vary between being one-third as good as the count to being three times as good as the count.

In making a trawling survey in poorly known conditions some trawling gear has to be selected. The last section of this paper shows that it is possible for conclusions even about relative fish abundance let alone absolute abundance per unit area of bottom to differ by roughly the same order of magnitude when sampled with different trawls. It is better then to put fair reliance on hydroacoustic equipment (the fastest search tool) and to back it up by sampling with more than one selection of trawl type and perhaps bottom-set gillnetting as well.

If all cod within the otter board spread of a Granton trawl with 40 fm sweeps were caught, the density of fish at the bottom would have to be some 30 fish per square cable below headline height to give an acceptable catch rate, say, 25 baskets—500 fish per hour. Real abundance must be greater than this by a variable factor dependent upon other variable factors related to escapes in the areas of otter boards, over the sweeps, over, under, and out of the net. At present, the range of this factor is not well understood due to lack of evidence. Very tentatively, let us say the factor may be upwards and downwards from four. Fish of that size would then have to be aggregated into concentrations close to the bottom of, say, upwards or downwards of 120 fish per square cable for fishing on them to be worthwhile.

As long as fish can be recorded as individuals in midwater and are not schooled up, fairly exact estimates (ICES/FAO Acoustic Training Course Report, 1969), can be made of the number per unit area in a given depth layer. Three ships with different echo sounders gave different estimates of number of echoes per square cable, attributable to large cod in Lofoten spawning area. Only one of three vessels was fitted to give echo density within four fm from the bottom and found a maximum density of 60 echoes per square cable. The other ships found higher densities up to 1,000 per square cable from midwater layers.

Often, fish echoes will be more easily counted in midwater by night so that if and when they have descended to the bottom during daylight at least their average density over the area can be known. When fish are close to the bottom an echo count or echo integration may still be made but with less expectation of accuracy and it may still be compared with the trawl catching rate.

The gap between estimates of abundance by echo sounding technique and by fishing is closing. A transducer towed above and within the triangle bounded by otter boards and net with its signals fed likewise to a

counter or integrator could give yet a third estimate of fish density in vicinity of the trawl and so help solve the trawl sampling efficiency problem. The understanding of trawl sampling efficiency is the road to improving it.

Schooling fish

Other species will school-up by day and disperse to surface waters or up to a thermocline by night. In such a case they are not available to bottom trawl, but dependent on water depth and clarity and upon illumination, the same species may at other seasons and other places school-up by night and descend to the bottom by day. Estimates are required of the number of fish in schools of a given size. The best estimates so far are for Menhaden where the school is spotted by aircraft and the complete school rung by purse seine (Reintjes, 1969). By camera and by acoustic techniques Truskanov and Scherbino (1965) have estimated the density of Atlanto-Scandian herring in a school as about one per cubic metre. A rather big but typical herring trace measured recently near Heligoland was 124 m across by 15 m deep, which assumed as discus shaped could just have been surrounded by a 275 fm long herring purse seine. Taking the above density and in round figures this could be 20 t of fish. Actually, these herring would be smaller but perhaps more tightly packed. This would not be an unreasonable catch for a purse seine net. Purse seine fishermen in Norway and Iceland are now supposed to be pretty good at estimating the catch weight to be expected from a school from their sonar and echo sounder records. Research workers do not yet seem to have acquired the technique, but let the skills of both be put together and we begin to have a method of abundance survey by counting the size and number of schools along the survey path on sonar and estimating the size of the fewer number under the ship by echo sounder. Should these schools disperse on to trawlable bottom, some measure of the trawl sampling efficiency may still be obtained. Research vessels with the more advanced hydroacoustic apparatus do not necessarily have to do all the trawl sampling. A commercial fleet operating in the area will give a better area coverage, utilizing various gear types and much more catch rate data.

OPTIMIZATION OF DESIGN

For developing countries the steps from simple selection, through select and modify to complete redesign of trawling gear can, and sometimes have, led to very considerable improvements in catching ability. There is a vast difference between poor gear and good gear and the transition may be made quickly, but to try to optimize the process of selection and design in relation to fish behaviour is a piecing together of slowly accumulating and often seemingly contradictory evidence.

The necessary information for optimization may not be acquired by experiments with trawling gear at all. The vitally important aspects of swimming speed and endurance reviewed by Blaxter (1969) is a case in point. Comparative fishing experiments devised to illuminate aspects of fish behaviour in relation to gear have to be so hedged about by conditions in order to obtain signifi-

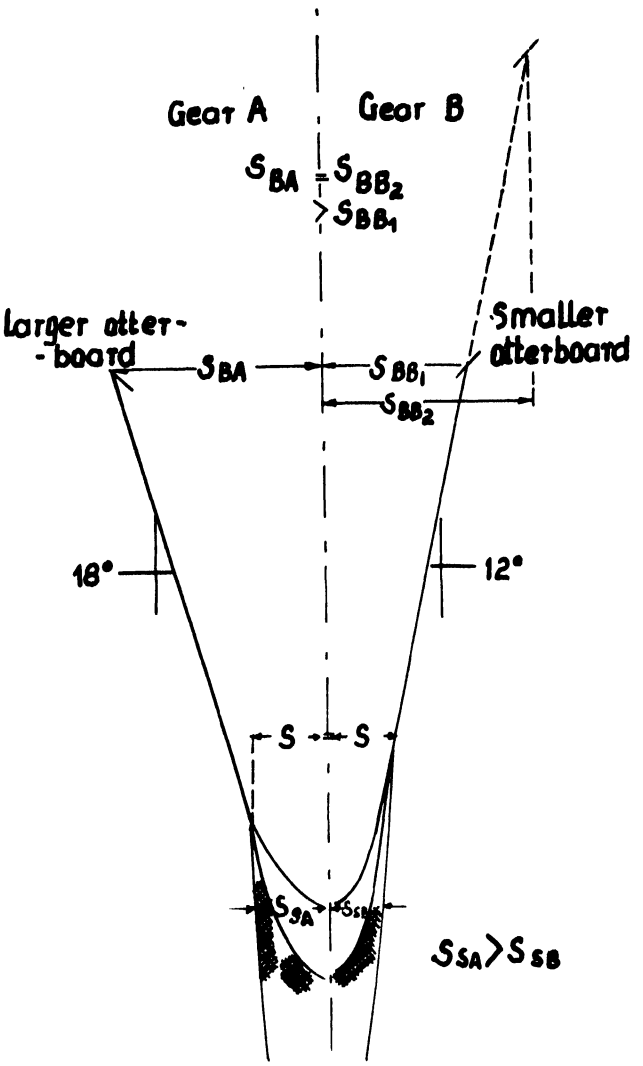

Fig 5. Why it is not possible to alter only one dimension in trawl comparisons

cant differences that only very closely qualified statements can be made about the significance of results. Determining objectives and the planning of comparative fishing experiments is tricky.

Consider fig 5. Here an attempt is made to compare the effect of sweep angle keeping other parameters the same as far as possible. How far is this possible?

(1) Headline height and towing speed are arranged to be the same. In the case of gear B, wings are lengthened to keep the net spread the same as A, the standard net.

(2) It is not possible to have both constant board spread and constant sweep length.

(3) It is not possible to have constant otter board size and therefore it cannot be determined whether the frightening effect of the otter boards is beneficial or otherwise in terms of fish catching; the best that can be done is to have sweeps long and the otter boards as remote from the net as possible.

(4) The lead in angle of the wings is dependent on the angle of the sweeps and therefore the lead in angle of the wings is also different for the two nets.

What is being compared is therefore not the effect of sweep angle but the effect of sweep angle and wing angle combined.

(5) Because of the lead in angle of the wings, the stretch of the nets across their squares is not the same ($S_{SA} > S_{SB}$). Thus if the nets are made with the same size of square, the same number of meshes across and in length and the same mesh size, the meshes in the square of net B will be rather more closed and the length of square in the fishing position will be slightly longer. The same will be true for the whole of the bag, that of net B will have its meshes more closed up laterally and elongated longitudinally. The open area ratio of the meshes will be greater in net A than in net B. If it is desired to have the open area ratio constant for the two nets then B must be redesigned. (See fig 6.)

If this is done, the original intention of comparing the effect of sweep angle only has become a comparison between the whole trawl gear A designed to work with a lead in angle of 18° and a trawl gear B designed to work with a lead in angle of 12°. When drawing conclusions about the experiment such distinctions are important.

Suppose it is found that gear B catches slightly less than gear A, what conclusions could be drawn? It can be said that A catches more than B but it is not safe to generalize and say that an 18° lead in is better than 12° lead in. By virtue of the smaller otter boards and $S_{SA} > S_{SB}$, particularly if net B is redesigned so that the meshes have the same open area ratio, then gear B will have less drag and require less propeller rpm to tow it at the same speed as A. If gear B is scaled up in size to have the same drag as gear A, it might catch more than A. Only if propeller rpm, drag, etc., are measured will it be possible to say how much B should be scaled up to have the same drag as A.

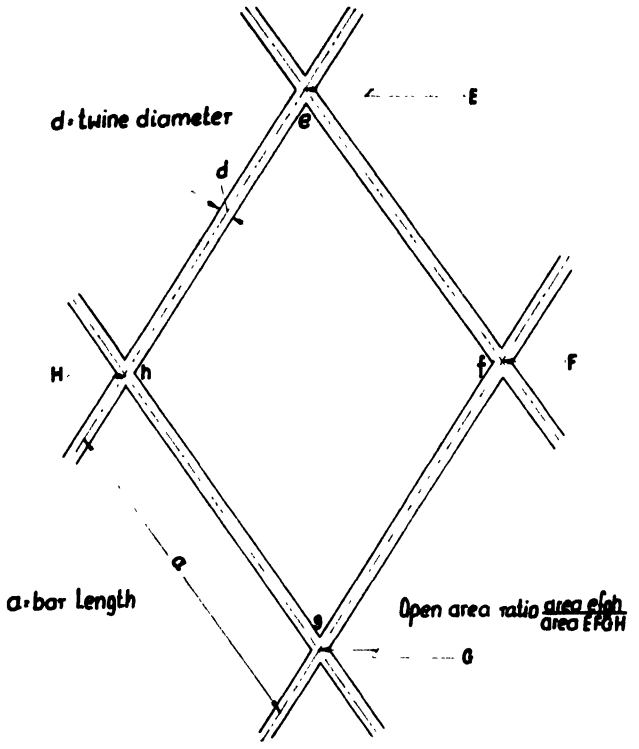

Fig 6. Open area ratio of netting

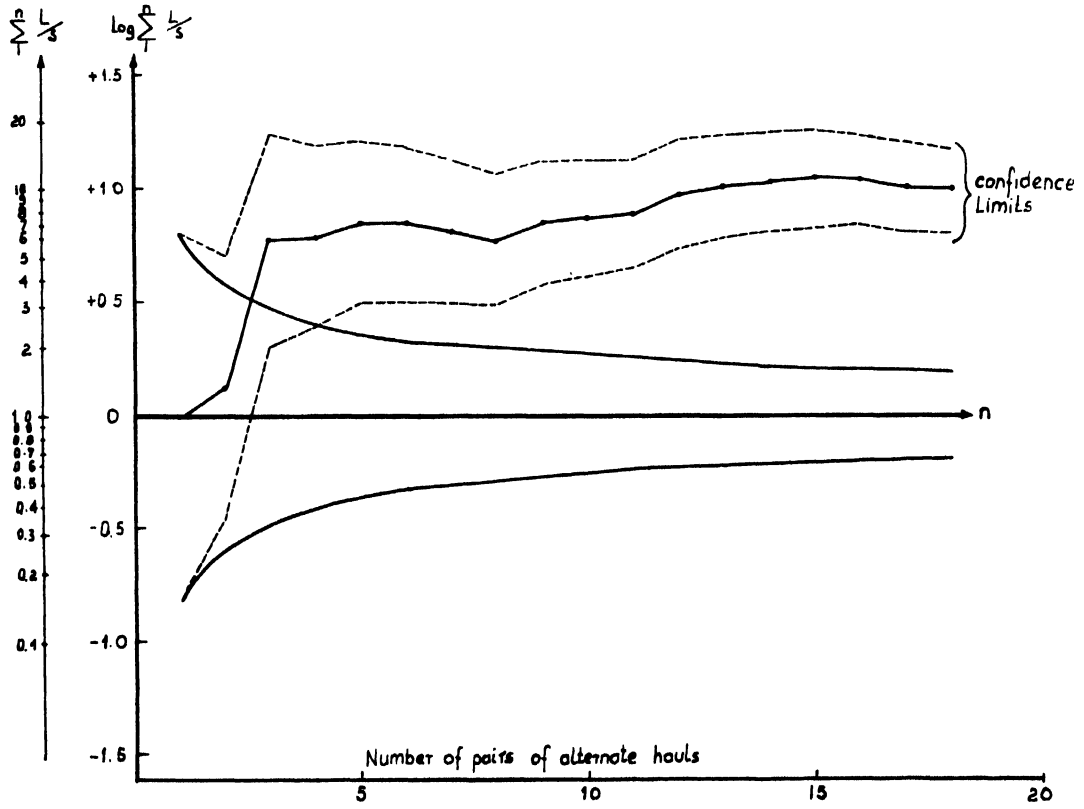

Fig 7. Evaluation of comparative trawling tests

Such a scaled up version of B with its longer wings is a more vulnerable net than A so that it is unlikely to be a better net than A on all fishing grounds. The next step in assessing the relative merits of the two types of gear would be to record and set some measure to the amount of damage sustained by the two gears. The number of spare parts used and the hours mending could be counted. What one gear catches in comparison with another per hour's fishing time is useful to know for some purposes. If, however, one gear takes longer to handle than the other, economic conclusions cannot be drawn unless measurement of the relative handling times have been made.

Drawing conclusions about a series of comparative fishing experiments is tantalizing; see Bridger's account (1969) of tests with the Granton and the SARO trawl. Covering nearly the same sets of trials, Foster (1969) elaborates mathematical interpretations relating observations on the swimming performance of fish and the results of comparative fishing experiments. Sweep length and the wire in front of the trawl made a big difference to catches, but concerning only the nets used, he reported that results to date did not support the suggestion that net shape and size had a high bearing on catching power.

From general considerations, Ionas (1966) believes that for a given species there must be a minimum size of trawl at which catching stops and it would follow that if a new trawl were smaller than the prototype, its catches would be worse than proportionally less.

By way of an example and put in another form, the results of a comparison between a large lightweight net and a small heavy net reported by Dickson (1964) are shown according to the method proposed by Gulland (1967) in fig 7 and in Table 1. Both nets were towed at approxi-

TABLE 1. HADDOCK

No. of pairs of hauls	*Number of fish* *Large net (L)*	*Small net (S)*	$\sum L/S$	$\log \sum L/S$	L/S	$\log L/S = x$	x^2	$\pm \frac{2S_x}{\sqrt{n}}$
1	2	2	1	0	1	0	0	0.812
2	64	47			1.4	0.15	0.023	0.575
	66	49	1.35	0.13				
3	558	43			15	1.18	1.39	0.47
	624	92	6.8	0.78				
4	64	15			4.3	0.63	0.395	0.406
	688	107	6.15	0.79				
5	206	16			12.9	1.11	1.23	0.362
	894	123	7.25	0.86				
6	271	40			6.8	0.83	0.69	0.332
	1165	163	7.15	0.85				
7	65	21			3.1	0.49	0.24	0.306
	1230	184	6.7	0.82				
8	111	37			3.0	0.48	0.23	0.288
	1341	221	6.06	0.78				
9	305	11			28	0.45	0.203	0.271
	1646	232	7.1	0.85				
10	194	16			12.1	1.08	1.17	0.256
	1840	248	7.4	0.87				
11	261	20			13	1.11	1.23	0.244
	2101	268	7.85	0.89				
12	724	32			22.6	1.35	1.82	0.235
	2825	300	9.45	0.98				
13	513	22			23.4	1.37	1.88	0.225
	3338	322	10.4	1.02				
14	440	35			12.5	1.10	1.21	0.217
	3778	357	10.6	1.03				
15	659	43			15.3	1.18	1.39	0.209
	4437	400	11.1	1.05				
16	791	61			13.0	1.11	1.23	0.203
	5228	461	11.3	1.05				
17	253	72			3.5	0.54	0.29	0.197
	5481	533	10.3	1.01				
18	401	55			7.3	0.86	0.74	0.192
	5882	588	10.0	1.0				

$n = 18$ $\quad \sum x = 15.01 \quad \sum x^2 = 15.361$

$\bar{x} = 0.835$

Variance $S_x^2 = \frac{1}{n-1} \sum (x-\bar{x})^2 = \frac{1}{n-1} (\sum x^2 - \bar{x} \sum x) = \frac{1}{17} \quad (15.361 - 0.835 \times 15.01) = 0.165$

$S_x = 0.406; \qquad 2S_x = 0.812$

Standard deviation after n hauls $= \frac{S_x}{\sqrt{n}}$

95 per cent confidence limits after n pairs of alternate hauls $\qquad L/S = \text{antilog} \left(\log \sum^{n} L/S \pm \frac{2S_x}{\sqrt{n}}\right)$

In the example, after 18 pairs of alternate hauls $L/S = \text{antilog} (1 \pm 0.192) = 10$ (ranging from 6.4 to 15.6)

mately the same speed (3 kn) with the same otter boards, sweep wires 15 fm and spreading wires 8 fm and both gears had about the same drag (1.3 t). The following are comparative dimensions of the nets:

	Large light net	*Small heavy net*
Headline length	70 ft	47 ft
Groundrope length	85 ft	60 ft
Size round throat	460 meshes × 114 mm	376 meshes × 89 mm
Twine (nylon)	210/30 and 210/45	210/60
Headline height	5.2 ft	4.0 ft
Otter board spread	124 ft	88 ft
Groundrope spread	43.3 ft	25 ft
Mouth area	185 sq ft	82 sq ft
Sweep angle	17°	13.5°

This refers to one series of tests only done in daylight and gave catch ratios of large net/small net for haddock 10:1 (95 per cent confidence limits 6.4 to 15.6); whiting 4.54:1 (limits 2.8 to 7.3) and all flatfish 1.28:1 (limits 1.0 to 1.6). Except for flatfish where it gave a better catch per unit of area swept, there may be an indication that for roundfish the small net was approaching the limit size of ineffectiveness. Yet for that power of vessel (180 hp) the trawl has to be almost as small and strong as that in order to work rough ground. Taking a rougher but wider view, that small trawl is smaller than any which according to the FAO Catalogue of Fishing Gear Designs have been found commercially acceptable for roundfish like haddock and whiting.

The rougher approach of collecting more data under less well controlled conditions is not to be discounted in these days of radio communication and data processing devices. With a trawling fleet in the Bering Sea, Lestev (1969) reported how out of a number of nets tried the best of these were soon discovered under operational conditions. He has some interesting things to say about tactics. Once, in the general area of fish and with the redfish schools in patches along an isobath and on rough ground, the trawl was towed above the bottom at full speed available until a school was located on the echo sounder, and then the vessel was slowed down allowing the trawl to sink and come through the fish. This increased the searching power and reduced net damage. Such requirements for fast off-bottom towing and short time on rough ground could alter the selection and design of gear quite a lot. It might even be shot and towed, closed, and an explosive device triggered via the netsonde cable cause it to open.

More generally, if gear specifications, haul by haul catch and gear damage records plus echo sounder record can be codified and relayed to a central point with data processing facilities (one of the fleet, a scouting, research or mother vessel or shore base) and given some minimum of operational research planning acceptable to the skippers then a new way is open for the selection and design of trawling gear for the development of fishing tactics—and not only for those.

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Choix du Chalut Semi-pélagique et de son Gréement selon la Puissance du Navire, le Comportement des Espèces Recherchées et la Nature du Fond

M. Portier

Determination of semi-pelagic trawl and its rigging according to the power of the vessel, the behaviour of species sought and bottom conditions

A development of semi-pelagic trawling has especially been observed in the northern harbours of France. Determination of the semi-pelagic trawl dimensions suitable to trawler towing power is obtained by using the notion of twine area. Depending on the species sought and its behaviour different types of semi-pelagic trawls have been designed, in particular for herring, mackerel and roundfish. According to types of fishing and bottom conditions, fork riggings or bridles and sweepline rigging can be used. This new technique, the adjustment of which is quite easy, definitely improves the fishing yield.

Elección de la red de arrastre semipelagica y del aparejo de remolque de la misma segun la potencia de la embarcación, el comportamiento de las especies deseadas y la naturaleza del fondo

La pesca semipelágica al arrastre ha progresado especialmente en los puertos del norte de Francia. Para determinar las dimensiones de una red de arrastre semipelágica teniendo en cuenta la potencia motriz de la embarcación que la remolca se emplea la noción de "superficie de los hilos". Según la especie que se persigue y su comportamiento se han establecido diversos tipos de redes flotantes de arrastre, en particular para el arenque, la caballa y los peces redondos. Finalmente, según la pesca practicada y la naturaleza del fondo, se emplean aparejos de remolque de horquilla o de brazos y nervios. Estas nuevas técnicas, bastante fáciles de aplicar, mejoran muy sensiblemente el rendimiento pesquero.

CES dernières années, on a vu se développer dans les ports du nord de la France, l'usage du chalutage semi-pélagique. D'abord utilisé comme complément du chalutage de fond pour la pêche des poissons bleus (hareng, maquereau, sprat), il remplace maintenant souvent celui-ci pour la pêche des poissons ronds (merlan, morue, lieu noir, merlu).

Le chalut semi-pélagique est caractérisé par des dimensions plus importantes que celles des chaluts de fond, des têtières en V largement ouvertes, un faible recouvre-

ment de dos et un corps de forme allongée. Son ouverture verticale est généralement double de celle du chalut de fond. Suivant la puissance du navire, l'espèce recherchée et le type de fond pratiqué, les chaluts semi-pélagiques ont des dimensions, des formes et des gréements différents. Dans tous les cas, ils sont employés avec des panneaux de fond rectangulaires ou ovales.

Determination des dimensions des chaluts semi-pélagiques

Les premiers chaluts semi-pélagiques avaient des dimensions importantes par rapport aux chaluts de fond, mais ils étaient réalisés avec des alèzes très fines, ce qui les rendait fragiles. Aussi les pêcheurs ne tardèrent pas à les alourdir en utilisant des alèzes plus fortes, du même type que celles employées pour les chaluts de fond. Dans ces conditions, les filets étaient encombrants et difficiles à remorquer. Il a donc paru nécessaire d'adapter les dimensions des chaluts semi-pélagiques à la force motrice des navires qui les utilisent.

Il est habituel de rapporter la dimension d'un chalut à la longueur de sa corde de dos. Ce principe, qui pouvait être valable lorsque les seuls engins en usage étaient des chaluts de fond, ne l'est plus pour des chaluts semi-pélagiques dont les formes sont différentes.

Nous avons donc introduit la notion de surface de fil pour déterminer les dimensions du chalut. En effet la résistance hydrodynamique de tout corps remorqué répond à la formule:

$$R = C\,Sp\,V^2$$

V^2 est le carré de la vitesse de déplacement

Sp représente la projection de la surface du corps dans le plan vertical normal au sens du déplacement

C est un coefficient qui ne peut être déterminé que par l'expérience.

Dans le cas de deux filets présentant une similitude de forme, on peut admettre que leur résistance à l'avancement sera proportionnelle à leur surface de fil. Cette surface est obtenue en calculant le nombre de mailles des pièces d'alèze comprises entre les têtières et l'amorce incluse, puis en multipliant ce nombre par le diamètre du fil et par quatre fois la dimension du côté de maille.

Nous avons pu déterminer sur la base des premiers chaluts semi-pélagiques expérimentés avec succès un rapport entre leur surface de fil et la puissance motrice des navires qui les remorquaient. Par la suite, les chaluts que nous avons calculés selon ce principe présentaient des dimensions bien adaptées à la force motrice des chalutiers (fig 1).

Il a été ainsi établi toute une gamme de plans de chaluts semi-pélagiques pour des forces motrices allant de 50 à 1.500 et 1.800 CV.

Sur la figure 1 apparaît également la surface de fil des chaluts de fond en fonction de la puissance des navires qui les remorquent. On constate que pour une même force motrice, le filet semi-pélagique présente une surface de fil plus importante que le filet de fond correspondant. Ceci est dû, sans doute, à ce que les chaluts semi-pélagiques, par rapport aux chaluts de fond, présentent des formes plus allongées et possèdent un bourrelet de moindre envergure et généralement moins lesté, correspondant à une traînée sur le fond moins importante.

Enfin nous avons établi la corrélation existant entre la surface de fil des chaluts semi-pélagiques et la dimension des panneaux qui leur sont adaptés. Dans tous les cas nous avons estimé que la vitesse moyenne de chalutage était de 4 noeuds (fig 2).

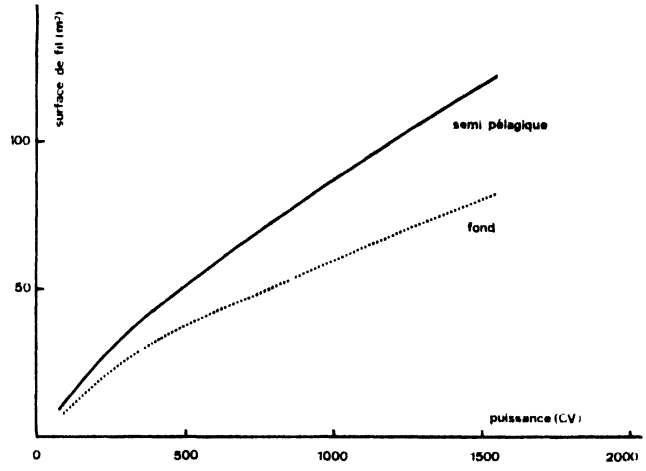

Fig 1. Surface de fil des Chaluts semi-pélagique et de fond en fonction de la force motrice des navires qui les utilisent

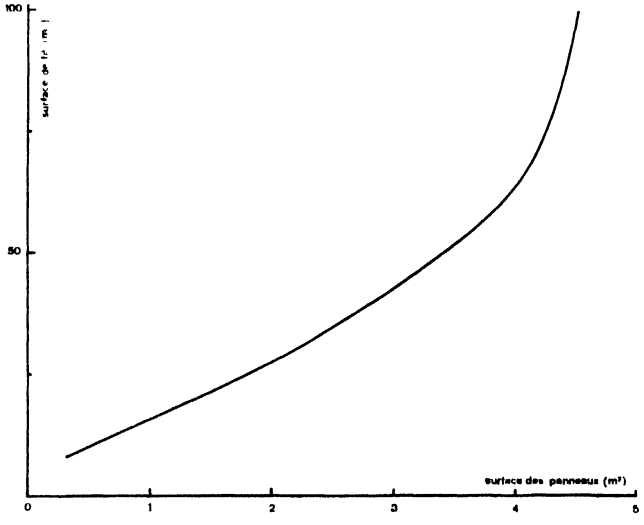

Fig 2. Expression de la surface de fil des chaluts semi-pélagiques en rapport avec la dimension des panneaux qu'ils nécessitent

Il est évident que si l'on reprend la formule $R = C\,Sp\,V^2$, il est possible de jouer sur l'un des facteurs afin de modifier l'autre. Ainsi la pêche du hareng bouvard ne nécessite pas une vitesse de traîne élevée, il est donc possible d'utiliser des chaluts de grande dimension, remorqués à 3,5 noeuds. Par contre, la pêche du maquereau, espèce particulièrement vivace, exige des chaluts légers remorqués à des vitesses supérieures à 4 noeuds.

Choix du chalut semi-pélagique et de son greement

Suivant le comportement de l'espèce recherchée et la nature des fonds pratiqués, différents types de chaluts semi-pélagiques et de gréements peuvent être employés.

Pêche du hareng

Le filet dérivant qui était employé exclusivement pour la pêche du hareng jusqu'aux années 1920 a été progressivement remplacé par le chalut de fond dans les années qui suivirent. Les captures les plus importantes furent alors réalisées sur des harengs pleins ou bouvards rassemblés sur les frayères. Mais pour capturer un poisson souvent décollé du fond avec des chaluts dont l'ouverture verticale ne dépassait pas 3 à 4 m (9 ft–13 ft) pour un bateau de 750 à 1.000 CV, on utilisait un ou même deux plateaux élévateurs qui, tout en augmentant l'ouverture du chalut, avaient un effet de rabattement et amélioraient le rendement.

L'introduction des chaluts semi-pélagiques dont l'ouverture verticale peut être double de celle du chalut de fond correspondant a permis de supprimer en partie ces artifices. Ainsi un chalut de 45,50 m (149 ft) de corde de dos et de 53,90 m (177 ft) de bourrelet (voir fig 3), remorqué par un bateau de 1.000 CV a une ouverture au niveau du ventre de 8 à 9 m (26 ft–30 ft).

Le gréement utilisé pour la pêche du hareng comporte des fourches dont la branche inférieure est de 20 à 30 m (65 ft–98 ft) et des bras de 50 m (164 ft). Les panneaux de fond peuvent être du type rectangulaire de 3 m sur 1,50 m (9 ft et 4 ft 7 in) et pesant 1.000 à 1.200 kg (2.204 lb–2.650 lb), ou du type ovale.

Le boulage est d'environ 40 à 50 boules de 4.1 (8,8 lb) complété généralement, dans ce genre de pêche, par un plateau élévateur. Le lestage est de 80 à 120 kg (177 lb–265 lb) de chaîne sur le bourrelet. Une chaîne de réglage à grandes mailles, placée à la jonction du bourrelet et du bras inférieur, permet de régler la différence existant entre le haut et le bas du gréement. Ainsi, portée à 3 m (9 ft) pour un passage du bourrelet sur le fond, cette différence peut être ramenée à 2 m (6 ft) pour un passage au-dessus du fond. Le filage utilisé est court

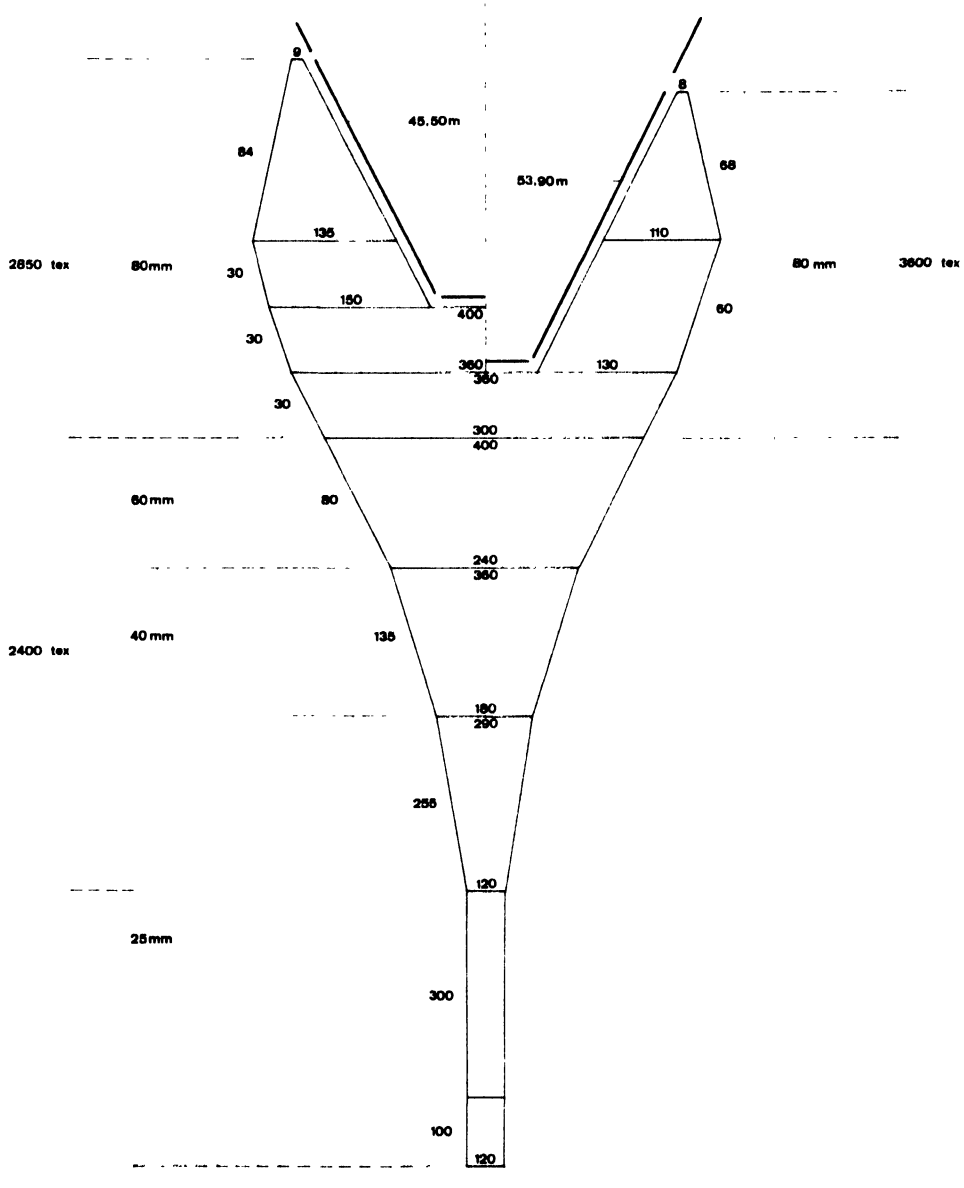

Fig 3. Chalut semi-pélagique au hareng de 45,50 m de corde de dos et 53,90 m de bourrelet utilisé par les bateaux de 1,000 à 1,500 CV

(3–3,5 fois la profondeur) ce qui facilite le travail en pêcherie.

Dans ces conditions, équipés de sonars, de sondeurs et de netzsondes, les patrons des chalutiers qui utilisent ce type de chalut et de gréement pratiquent une véritable "chasse" du hareng. Ils passent la majeure partie de leur temps à la recherche de la détection, ne filant le chalut que lorsque celle-ci est repérée sur le fond ou au voisinage du fond. Il ne paraît pas nécessaire, pour effectuer la capture de ces concentrations importantes de harengs souvent peu vivaces, d'avoir une vitesse de traîne élevée. C'est pourquoi les chaluts utilisés dans ce genre de pêche ont des dimensions très importantes et sont remorqués à des vitesses inférieures à 4 noeuds.

Pêche du poisson rond (merlan, morue, lieu noir, merlu)

Pour la pêche des poissons ronds, on utilise des chaluts du même type que ceux utilisés pour la pêche du hareng. Toutefois, ils ont en général des dimensions relativement moins importantes, car d'une part ils sont réalisés en alèze de chalut de fond et d'autre part ils doivent permettre une bonne vitesse de traîne. Suivant la nature des fonds, deux types de gréement peuvent être employés, le gréement à entremises et bras et le gréement à fourches.

Gréement à entremises et bras: Ce type de gréement est à préconiser pour les fonds réguliers, même durs. Il comporte des entremises plus longues que celles employées normalement avec un chalut de fond. En règle générale, la longueur des entremises hautes et basses est au moins égale à la longueur de la corde de dos afin de permettre au chalut de se déployer largement en hauteur. L'entremise milieu joint le prolongement de la ralingue de côté, au milieu de l'entremise haute (voir fig 4). Il n'est pas nécessaire d'utiliser un guindineau et la liaison des entremises avec les bras peut se faire au moyen d'un petit triangle d'acier pouvant passer dans les réas de potences et dans les guide-câbles. On pourra ainsi virer les entremises sur les tambours du treuil à la suite des bras.

Afin d'obtenir un bon effet de rabattement du poisson, les bras auront la plus grande longueur possible, 30 à 100 m (98 ft–328 ft) suivant les sondes, et le filage sera le même que pour un chalut de fond soit 3,5 à 6 ou 7 fois la profondeur.

La flottabilité du chalut est donnée par des boules de 4 l, réparties à raison d'une boule (8,8 lb) tous les mètres dans les ailes et de 2 boules par mètre dans le carré; ce boulage est complété éventuellement par un plateau élévateur amarré directement sur la corde de dos.

Pour les fonds durs on utilise un double bourrelet, en fil d'acier garni de rondelles de caoutchouc. Sa longueur est égale à celle de la ralingue inférieure du filet qui est un filin d'acier fourré de bitord ou un filin mixte. Les deux bourrelets sont reliés entre eux par des chaînettes de 0,30 à 1 m (1 ft–3 ft) de longueur. Ces chaînettes dégagent du fond l'alèze du ventre du chalut et évitent ainsi des avaries. Le lestage du bourrelet est au minimum de 1 kg (2,2 lb) par mètre dans les ailes et de 10 à 15 kg (22–33 lb) par mètre dans le carré. Il peut être augmenté sur les bons fonds.

Gréement à fourches: Ce gréement qui est celui qui a été décrit pour la pêche du hareng convient surtout aux fonds irréguliers, à ridens ou à buttes. Il permet d'avoir un chalut bien ouvert en hauteur, tout en employant des bras courts—en général 20 à 50 m (64 ft–164 ft) (fig 5).

Dans le cas particulier de la pêche sur des fonds très durs—pêche de la morue à Terre Neuve ou pêche du merlu sur les côtes d'Espagne—le bourrelet peut être remplacé par une ligne de sphères. Des chaluts de 41 m (135 ft) de corde de dos et de 49,80 m (164 ft) de bourrelet, réalisés en tresse de nylon de diamètre 3 mm (0,12 in) et 4 mm (0,16 in), sont utilisés avec succès par

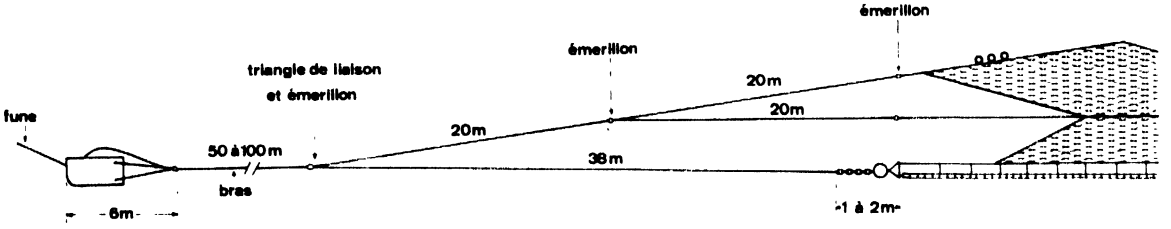

Fig 4. Gréement à entremises et bras d'un chalut semi-pélagique de 35 m de corde de dos et 42 m de bourrelet utilisable par des bateaux de 800 à 1,200 CV pour la pêche du poisson rond sur les fonds réguliers

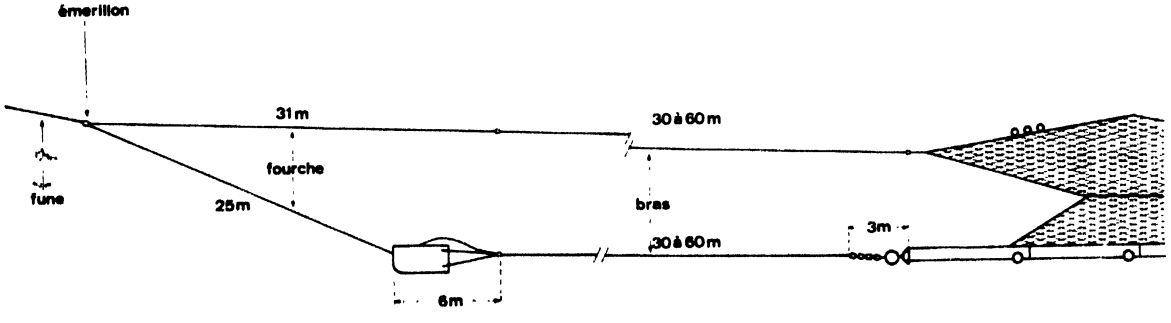

Fig 5. Gréement à fourches d'un chalut de 41 m de corde de dos et 49,80 m de bourrelet utilisé avec une ligne de sphères pour la pêche de la morue et du merlu sur des fonds irréguliers et très durs

des chalutiers de grande pêche de 1.800 à 2.000 CV. Le gréement comporte un brin de fourche inférieur de 25 m (82 ft) et des bras de 30 à 60 m (98 ft à 196 ft).

Pêche du maquereau

Pour la pêche du maquereau, espèce particulièrement vive, les bateaux de pêche artisanale de 150 à 400 CV utilisent des chaluts semi-pélagiques aux formes très allongées (fig 6), réalisés avec des fils fins et possédant des mailles de 100 mm (approx. 4 in) de côté à l'entêture.

Ces chaluts, dont la surface de fil et par conséquent la résistance à l'avancement sont très faibles, ne fonctionnent bien qu' avec des panneaux plus légers que ceux utilisés en chalutage de fond normal.

Ainsi pour un bateau de 300 CV, utilisant le chalut de la fig 6, des planches de 1,80 m (6 ft) sur 0,90 m (3 ft) et pesant 200 kg (440 lb) sont suffisantes. En plus des bras, le gréement comporte soit des longues entremises de 20 m (64 ft), soit des entremises de 10 m (32 ft) avec un guindineau de 0,60 m (2 ft).

Dans ces conditions, il est possible de chaluter à des vitesses supérieures à 4 noeuds, ce qui est particulièrement favorable à la pêche du maquereau.

Conclusion

Le chalut semi-pélagique de dimensions bien adaptées à la force motrice du chalutier et au genre de pêche pratiquée se révèle être un engin efficace d'un emploi aisé. L'augmentation de son ouverture verticale améliore son pouvoir de capture sur les espèces qui sont décollées du fond. L'utilisation d'un gréement adapté à la nature des fond permet notamment de prospecter avec des risques

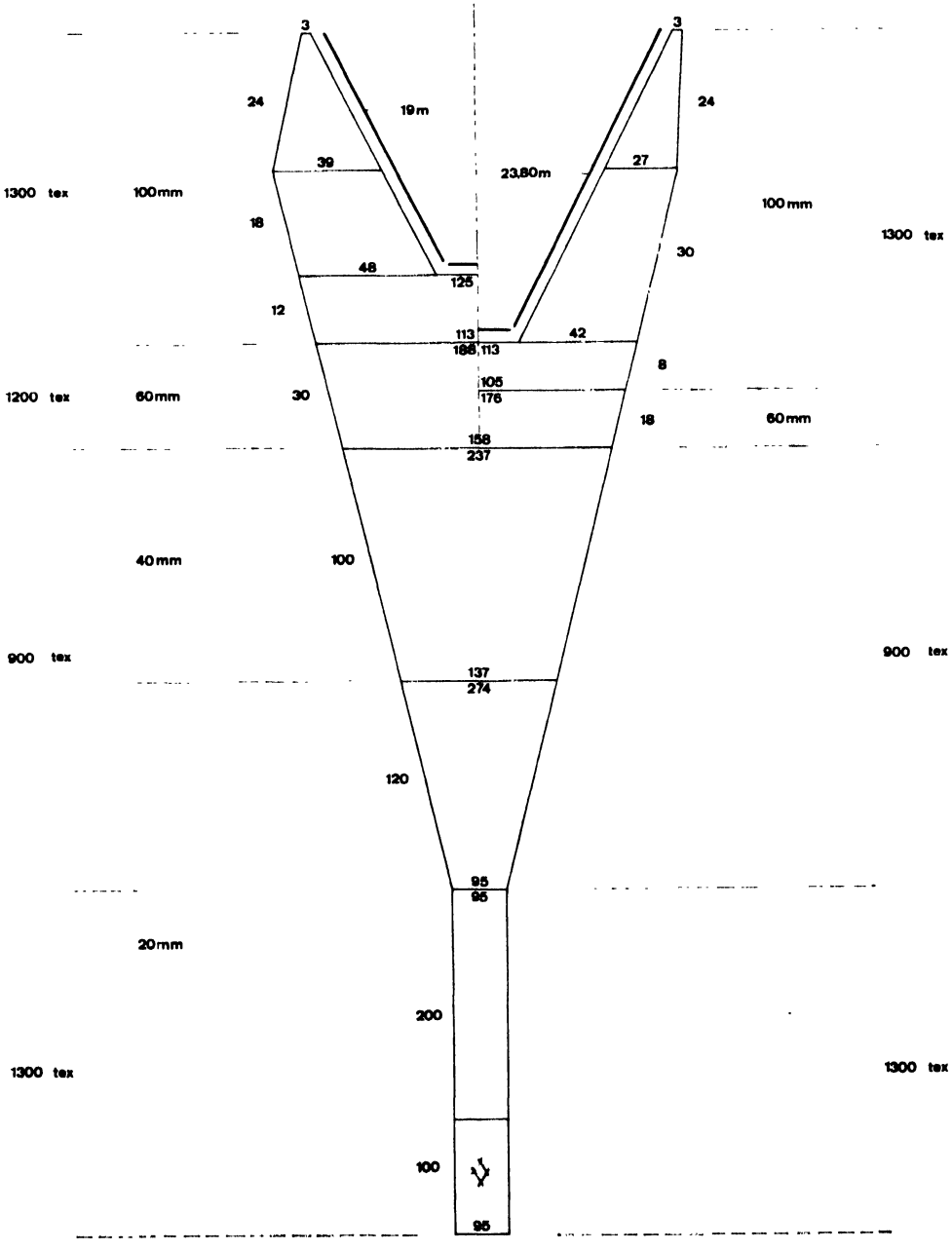

Fig 6. Chalut semi-pélagique de forme très allongée utilisé par un bateau de 300 CV pour la pêche du maquereau

très réduits d'avaries des lieux de pêche productifs qui étaient auparavant impraticables ou par trop dangereux pour les chaluts de fond. Les patrons de pêche expérimentés qui ne se laissent pas décourager par les quelques mises au point indispensables trouvent toujours leur avantage à l'emploi de cet engin.

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A Calculation Method for Matching Trawl Gear to Towing Power of Trawlers

T. Koyama

Une méthode de calcul pour l'adaptation de la taille de l'engin de pêche a la puissance de remorquage des chalutiers

La méthode de calcul proposée a été mise au point sur la base d'observations faites à bord de six chalutiers de jauge brute comprise entre 300 et 3.500 tx. Cette méthode est présentée comme un moyen pratique pour déterminer la puissance effective de remorquage utilisée en chalutage, les performances requises pour le treuil de pêche, les caractéristiques de chalut, des panneaux divergents et des funes, en considération de la puissance du moteur principal et de la taille du navire.

Calculo para equiparar las dimensiones de la red de arrastre y la potencia de remolque de los arrastreros

Este método de efectuar los calculos se basa en las observaciones hechas a bordo de seis arrastreros de 300 a 3.500 toneladas brutas. Se ofrece como un procedimiento práctico para determinar la fuerza motriz de remolque efectiva empleada en el arrastre, el rendimiento requerido de la maquinilla de arrastre, las características del arte, de la puertas y de los cables, con respecto a la potencia del motor principal y al tamaño del barco.

MOST modern Japanese trawlers are sterntrawlers ranging from 300 to 4,000 GT. An important problem for trawl technologists today is how to match size of trawl gear to towing power or main engine output. As a result of studies of this problem during the past several years, the following computation methods are proposed to assess towing power and respective proper size of gear components such as trawl net, otter boards and warps, including trawl winch.

TOWING POWER

Towing power of a trawler is influenced by output of its main engine, shape of hull, propeller design (diameter, pitch and developed blade area), and trim of vessel under operation. It is, therefore, very difficult to accurately compute towing power. Strictly speaking, each trawler has its own towing power, so results of this calculation method will be approximate only. It was developed empirically by trials with six trawlers of 300 to 3,500 GT built in Japan between 1964 and 1967. The main specifications are given in Table 1.

The towing power (EHP) is the power required for towing the gear without taking into account the hull resistance.

When the total resistance of the gear is R′ (kgf) and the towing velocity is V(m/s) the EHP is $\frac{R' \times V}{75}$ $\left(\frac{\text{kgf} \times \text{m}}{\text{s}}\right)$ in horse power. The shaft hp (brake hp) (BHP) is obtained by multiplying the indicated hp (IHP) by engine efficiency. According to our observations, the relation between the EHP and the BHP of the tested trawlers is almost proportional and can be expressed as follows:

$$\text{EHP} = \text{K(BHP)} \qquad (1)$$

On a calm sea when the main engine is 1,200 hp and the propeller diameter is 2,400 mm, the value of K is about 0.18. When the hp is 2,700–3,150 and the diameter is 2,950 mm, it is about 0.22. When they are 3,500 hp and

TABLE 1. SPECIFICATIONS OF THE TRAWLERS USED FOR THE EXPERIMENTS

	No. 3 Heian maru	*No. 83 Taiyo maru*	*No. 81 Taiyo maru*	*No. 82 Taiyo maru*	*Zuiyo maru*	*Shoyo maru*
Length (oa) (m)	39.80	73.79	88.20	88.20	88.20	99.50
Breadth (m)	8.00	12.10	14.00	14.00	14.00	15.50
Depth (m)	3.90	5.75	9.20	9.20	9.20	10.00
Main engine type	Nigata 6MG31 4 cycle diesel	6 UET 45/75 2 cycle diesel	7 UET 45/75 2 cycle diesel	7 UET 45/75 2 cycle diesel	7 UET 45/75 2 cycle diesel	8 UET 45/75 2 cycle diesel
Maximum continuous shaft hp BHP (hp)	1200	2700	3150	3150	3500	4000
Maximum engine speed (rpm)	550	225	225	225	235	240
Gross tonnage	314	1500	2800	2900	3000	3400
Propeller type	CPP	fixed	fixed	fixed	fixed	fixed
Propeller diam (mm)	2400	2950	2950	2950	3040	3150
Propeller pitch (mm)	1440	2050	2210	2220	2110	1970
Propeller developed blade area (m^2)	1.936	4.580	4.440	4.440	5.382	5.058
No. of blades	3	5	5	5	5	5
Trawl winch performance	8 tf 80 m/min	15 tf 70 m/min	18.6 tf 60 m/min	18.6 tf 60 m/min	19.7 tf 66 m/min	20 tf 80 m/min

3,040 mm respectively it is about 0.27. When they are 4,000 hp and 3,150 mm it is about 0.3. Generally speaking, the value of K increases with increasing hp and propeller diameter (Koyama, 1965, 1966, 1967).

In Japan, for indicating the hp of a main engine, the maximum continuous shaft hp is adopted. Generally about 60 per cent of this maximum continuous shaft hp is used as the EHP during trawling. Of course more than 60 per cent may be used in rough weather, but for calculations it is recommended to use 60 per cent of continuous BHP as a standard for EHP.

As an example, on the assumption that other conditions such as diameter of propeller, etc. are as given in Table 1, 60 per cent of 3,150 BHP used during trawling would be 1,890 hp. According to formula 1 the value of K would be 0.22 and we obtain:

$$\text{EHP} = 1{,}890 \text{ hp} \times 0.22 = 415 \text{ hp}$$

Thus the towing power which is effectively used of 3,150 continuous BHP can be estimated at about 415

Since 1 hp is by definition $\frac{75 \text{ kgf} \times \text{m}}{\text{s}}$

the towing power would be:

$$415 \text{ hp} = \frac{75 \text{ kgf} \times \text{m}}{\text{s}} \times 415 = \frac{31.1 \text{ tf} \times \text{m}}{\text{s}}$$

Assuming a trawling speed in calm water of 4.5 kn or 2.25 m/s, the towing resistance of the whole gear at this speed is as follows:

$$\frac{31.1 \text{ tf m/s}}{2.25 \text{ m/s}} = 13.8 \text{ tf approx.}$$

The trawl gear for this trawler should be designed to have a total resistance of 13.8 tf approximately at the towing speed of 4.5 kn. For example in a rough sea with a head wind of Beaufort 6 the EHP drops down to about one half of its value in calm weather. From this fact it can be said that the towing velocity of 4.5 kn in calm weather drops down to about 3.5 kn in a rough sea with a head wind, because the power to pull the trawl or EHP increases in proportion to the cube of the towing velocity, i.e. $(3.5 \text{ kn})^3/(4.5 \text{ kn})^3 = \frac{1}{2}$ approximately.

TRAWL WINCH

It is no exaggeration to say that the trawl winch of a trawler is as important as its main engine. When hauling is started in rough weather, the tension exerted on the trawl warps increases abruptly, due to the scooping action of the swell, from the moment the otter boards leave the sea bottom; then the transient maximum tension becomes

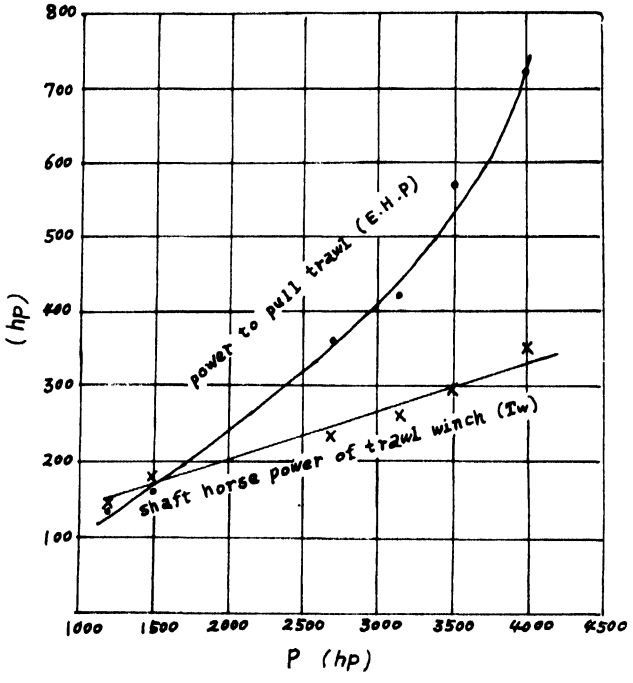

Fig 1. Relation between the maximum continuous shaft horse power of the main engine P (hp), *the shaft horse power of the trawl winch* Tw (hp) *and the available towing power E.H.P.* (hp) *of present*

TABLE 2. RELATION BETWEEN MAXIMUM CONTINUOUS SHAFT HORSE POWER OF MAIN ENGINE *P* (hp) AND SHAFT HORSE POWER *Tw* (hp) OF THE TRAWL WINCH ON PRESENT JAPANESE TRAWLERS

Gross tonnage	*Maximum continuous shaft horse power of the main engine P(hp)*	*Power to pull trawl EHP (hp)*	*Trawl winch*	
			Performance tf × m/min	*Shaft horse power Tw (hp)*
314	1200	130	8×80	142
540	1500	162	10×80	176
1500	2700	360	15×70	234
2800	3150	415	18.6×60	248
3000	3500	570	19.7×66	293
3400	4000	720	20×80	350

three to four times that of the tension during the towing operation (Koyama, 1968). This should be remembered when designing a trawl winch and sufficient allowance should therefore be given to its performance. If it is driven by electro-motor, a low speed motor with great torque is needed. To meet the trend that trawling grounds have been shifting to deeper waters, the hauling speed of the winch is also to be as fast as 70 to 80 m/min at mean drum diameter. This is why larger and stronger trawl winches are requested today.

Table 2 and fig 1 show the relation between the power to pull the trawl computed in accordance with preceding paragraph and the shaft hp of the trawl winch installed on investigated trawlers. From the diagram it is clear that the power to pull the trawl (EHP) and the shaft hp of the trawl winch (Tx) are nearly the same in the case of trawlers of 314 to 540 t class (1200 to 1500 hp), but with the increasing size of trawlers, the winch shaft hp is smaller than the towing power.

If the towing speed during hauling is slowed down to half the required shaft hp of the trawl winch for maintaining the speed of the gear while hauling in, the warp would be one half of the EHP. If a higher hauling speed, for instance 80 m/min, is required, the shaft hp of the winch must be greater than one half of the EHP if the towing speed is not slowed down to less than half. It has to be nearly equivalent to the EHP as observed for the 314 to 540 t trawlers. However, it is not always possible, due to insufficient space on deck, to install a large trawl winch with a shaft hp as great as the EHP. In such a case there is often no other way than to control the speed of the winch during hauling operation.

According to fig 1 the relation between the shaft hp of the winch (Tw) in use today and the hp of the main engine (P) is as follows:

$$Tw = 80 + 0.06\,P \qquad (2)$$

TRAWL NET

Although they are equally designed and uniformly fabricated, trawl nets do not have uniform resistance if there is a difference in the buoyancy of their floats or in the spreading of their wings. It is very difficult, therefore, to accurately compute the resistance of a trawl net.

The empirical formula which has been introduced here is an approximate expression obtained from the results of experiments carried out by the author on ten kinds of trawl nets used by seven different trawlers of 100 GT

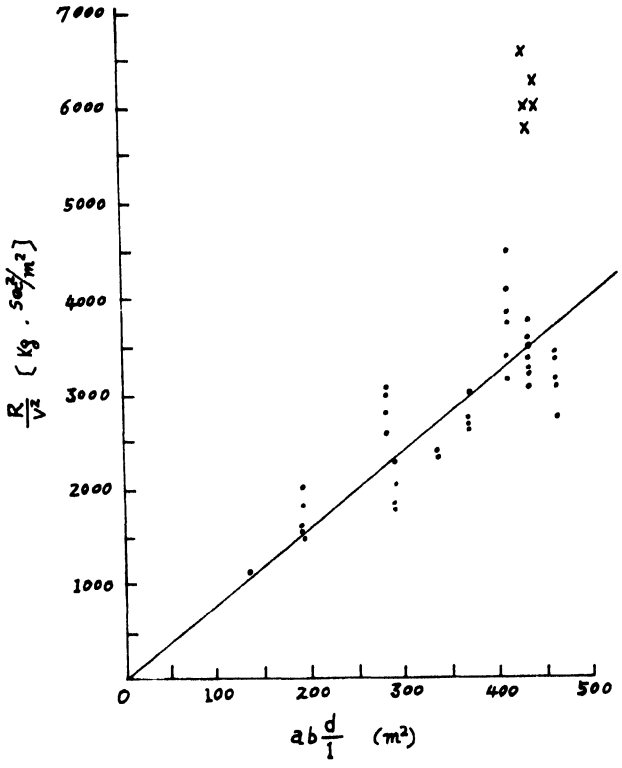

Fig 2. Relation between $\frac{R}{V^2}$ *(kgf s²/m²) and ab* $\frac{d}{l}$ *(m²) for present Japanese bottom trawls. . = no catch; X = about 1.5 t gilled fish*

with 300 hp engines to 3,500 GT with 4,000 hp engines. These experiments have been conducted under common and normal conditions, i.e. the total buoyancy of the floats (200 to 650 kgf), total weight in water of the ground bobbins greater than the total buoyancy of the floats by 20 to 30 per cent, netting made of polyethylene twine knotted, towing velocity 3.0 to 4.7 kn, and opening spread of wings 15 to 35 m. The results (fig 2) show that there is an almost direct proportion between R/V^2 (kgf s²/m²) and ab d/l (m²).

R (kgf) = resistance of trawl net

V (m/s) = towing velocity

a (m) = the maximum circumference of the net (shown by dotted line in fig 3)

b (m) = the maximum length of the net (shown by solid line in fig 3)

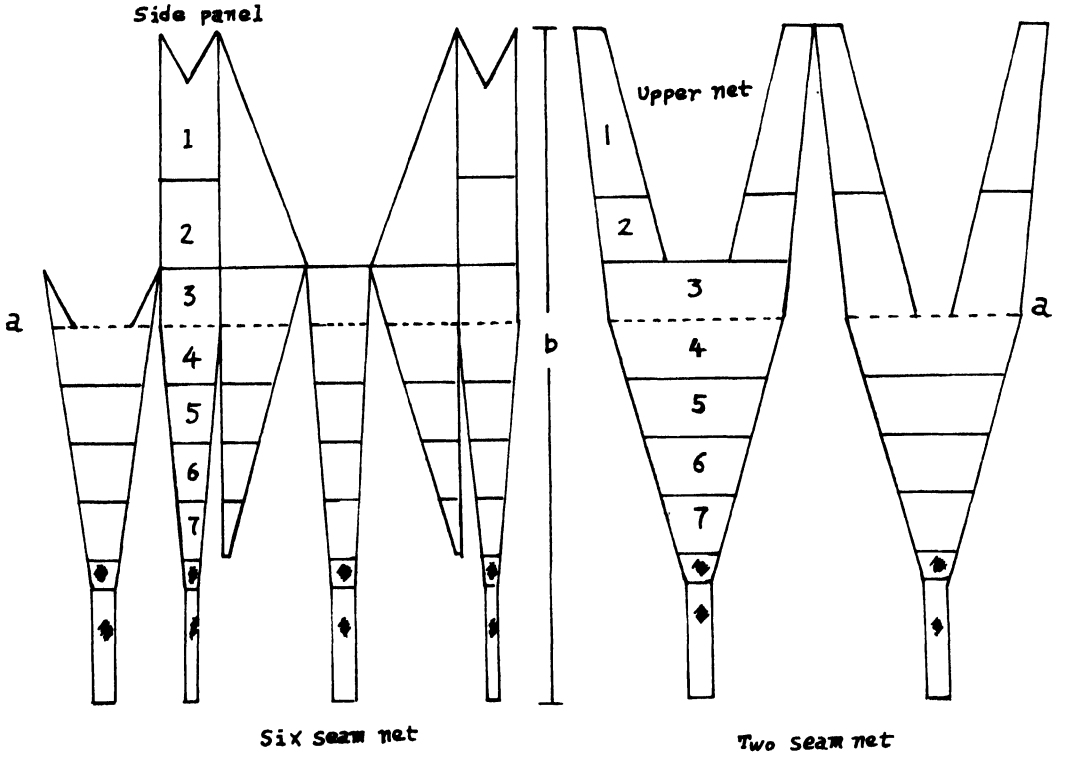

Fig 3. Method of calculating the towing resistance of trawl nets. The sections used for the two main net types are indicated by 1 to 7. a: maximum circumference; b: maximum length

d/l = in case of four and six seam nets: the average value of the ratio: d = diameter of the net twine to l = length of each mesh bar at side panel sections 1 to 7 in fig 3

d/l = in case of two seam nets: the average value of the ratio: d = diameter of the net twine to l = length of each mesh bar at upper net, sections 1 to 7 in fig 3.

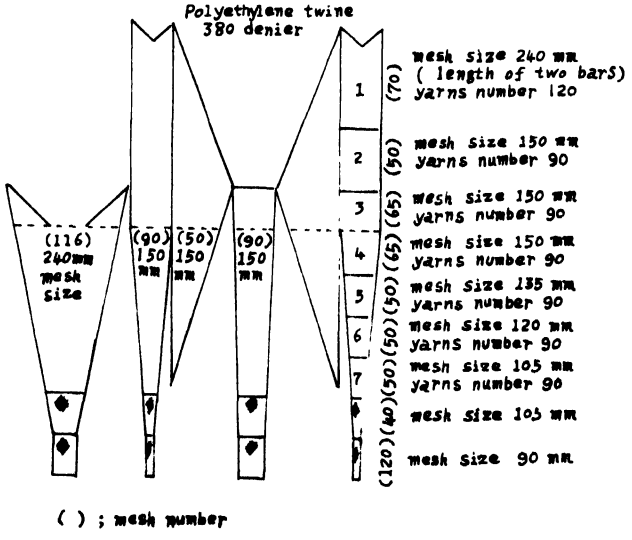

Fig 4. Example of a 6 seam bottom trawl for calculating towing resistance

The d/l of the intermediate piece and of the codend is not included in the above average ratio because uniformity cannot be expected in these parts due to use of double twines in some trawl nets.

Then, from fig 2 the resistance of a complete trawl net (with accessories) (R) with no fish catch is expressed approximately by Koyama (1967):

$$R = a\,b\,V^2\,d/l \qquad (3)$$

As an example the resistance of a large trawl, the construction of which is shown in fig 4, could be calculated as follows:

a = 24 cm × 116 + 15 cm × 140 × 2 + 15 cm × 90 = 83.34 m

b = 24 cm × 70 + 15 cm × 50 + 15 cm × 65 + 15 cm × 65
+ 13.5 cm × 50 + 12 cm × 50
+ 10.5 cm × 50 + 10.5 cm × 40
+ 9 cm × 120 = 76.8 m

d/l:
Section 1 : 3.67/120 = 0.0306
Section 2 : 3.2/75 = 0.0427
Section 3 : 3.2/75 = 0.0427
Section 4 : 3.2/75 = 0.0427
Section 5 : 3.2/67.5 = 0.0474
Section 6 : 3.2/60 = 0.0534
Section 7 : 3:2/52.5 = 0.061

The average value of d/l is 0.0458

$ab\,d/l = 83.34 \times 76.8 \times 0.0458 = 292$

$R = 8 \times 292\ V^2$, and with a velocity (V) of 4.5 kn (2.25 m/s), R = 11.8 tf.

Since the old days, in Japan, the size of a trawl net has been indicated by the length of the headline. A survey showed that the relation between main engine hp (P)

TABLE 3. RELATION BETWEEN MAXIMUM CONTINUOUS SHAFT HORSE POWER OF MAIN ENGINE P (hp) AND LENGTH OF HEADLINE OF TRAWL NETS H (m) OF PRESENT JAPANESE TRAWLERS

Gross tonnage	*Maximum continuous shaft horse power of the main engine P (hp)*	*Length of headline H (m)*
314	1200	49.94
1500	2000	51.20
1500	2700	60.50
1500	2700	58.10
1850	3150	61.90
1850	3150	61.90
2800	3150	59.95
2800	3150	61.90
3000	3500	60.00
3000	3500	65.00

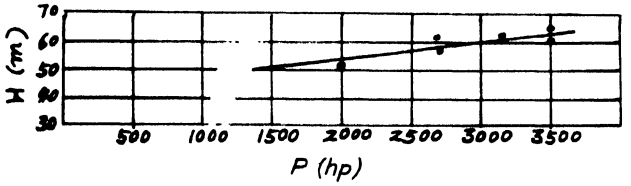

Fig 5. Relation between maximum continuous shaft horse power of the main engine P (hp) *and the headline length of bottom trawls* H (m) *for present-day Japanese trawlers*

and headline length (H) of trawl nets in use today (Table 3 and fig 5) can be expressed approximately as:

$$H = 42 + 0.006\,P \qquad (4)$$

However, it is considered that the value of ab d/l (m^2) is preferable for calculating the resistance of trawl nets.

Otter board

In Japan, the upright curved type of otter board (fig 6) which resembles the Süberkrüb otter board (Süberkrüb, 1959) is widely used. This type of otter board has less drag and greater spreading force compared with the flat type.

According to Schärfe (1959), with that kind of otter board the optimal angle of attack is about 15° giving a drag co-efficient of only about 0.3.

In practical fishing the maximum spreading force of these otter boards is secured by respective adjustment of the brackets. It is therefore assumed that the angle of attack is in practice about 15° and consequently there would not be much error in using 0.3 as a resistance co-efficient for computations. The resistance of an otter board R″ (kgf) is expressed as follows:

$$R'' = \tfrac{1}{2} C_d \rho V^2 S \qquad (5)$$

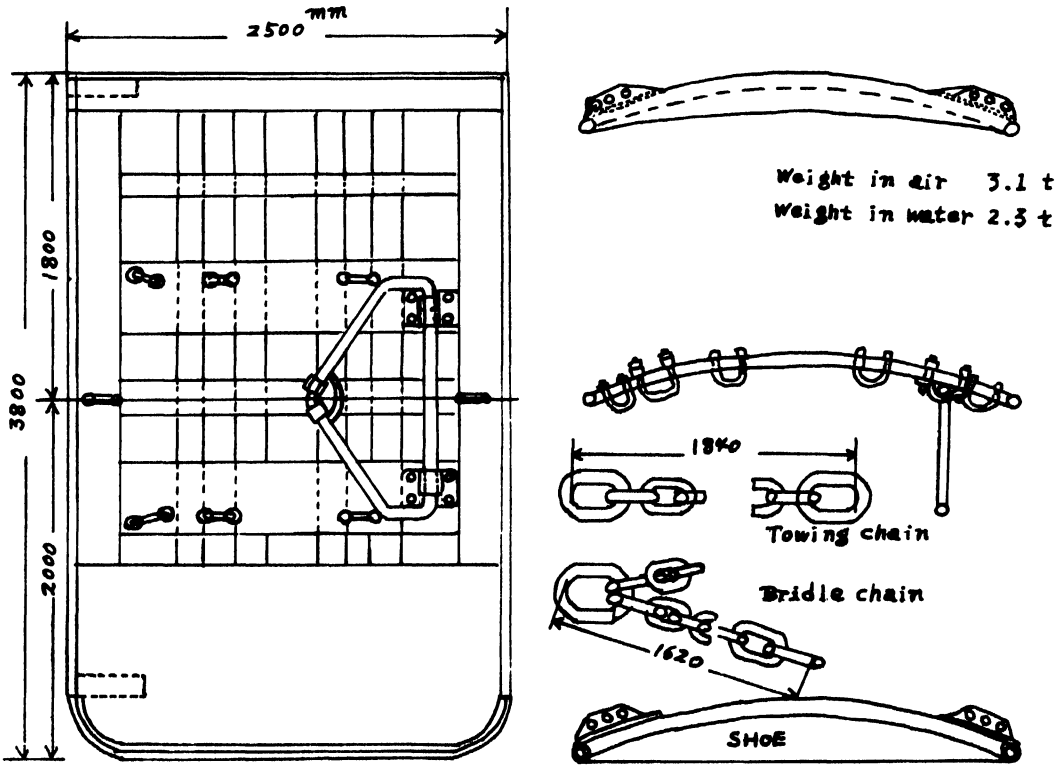

Fig 6. Curved upright otter board used for bottom trawling by 3,150 hp type Japanese trawlers

TABLE 4. RELATION BETWEEN MAXIMUM CONTINUOUS SHAFT HORSE POWER OF MAIN ENGINE P (hp) AND OTTER BOARD SIZE AND WEIGHT OF PRESENT JAPANESE TRAWLERS

Maximum continuous shaft horse power of the main engine P (hp)	*Otter board height (m)*	*Otter board width (m)*	*area S (m^2)*	*Weight of otter board in air W (t)*
700	3.2	1.36	4.080	0.800
850	3.2	1.60	5.120	1.040
1200	3.2	1.92	6.144	1.635
2000	4.0	2.00	8.000	2.100
2700	3.8	2.50	9.500	2.600
3150	3.8	2.50	9.500	3.100
3500	3.9	2.65	10.335	3.200

C_d = resistance coefficient; ρ = density of sea water, i.e. 105 (kgs^2/m^4); V = towing velocity (m/s); S = area of otter board (m^2).

As an example the resistance of a pair of curved otter boards of 3.8 m in height and 2.5 m in width would be:

$$R'' = \tfrac{1}{2} \times 0.3 \times 105 \times 3.8 \times 2.5 \times V^2 = 150 \times V^2$$

If the towing speed is 4.5 kn (2.25 m/s), the resistance (R") of one board is about 0.8 tf and the total resistance of a pair is about 1.6 tf.

Table 4 shows the relations found between the hp of the main engine (P) and the area (Sm^2) and weight in air (Wt) of the otter boards employed by Japanese trawlers today. Plotted on a logarithmic graph the figures of Table 4 form straight lines (fig 7) and accordingly the relation between the hp of the main engine P (hp) and the area of the otter board S (m^2) can be expressed approximately as:

$$S = 0.0945\, P^{0.68} \qquad (6)$$

and the relation between P and otter board weight in air $W(t)$ as:

$$W = 0.00478\, P^{0.8} \qquad (7)$$

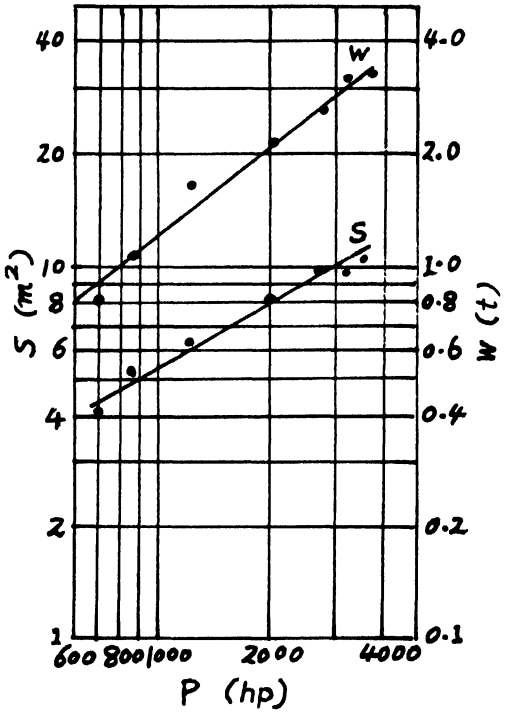

Fig 7. Relation between maximum continuous shaft horse power of the main engine P (hp) *and the otter board of present-day Japanese trawlers.*
W = *weight in air (t):* S = *area (m^2)*

As the above relations have been developed in practical fishery by repetition of trial and error, it is fairly safe to refer to them for the suitable size of otter boards for any main engine's horse power.

Function of the otter board is to provide desired distance between the wings. It should have great spreading force and small resistance. The stability of otter boards must also be taken into consideration. To obtain sufficient working stability, the majority of the upright type otter boards in use today have a height to width ratio of only 1.5 to 1.

To further improve stability, the centre of gravity is lowered by fixing floats to the upper section and weights to the lower part of the board (Koyama *et al.*, 1968).

Trawl warps

The structure of most of the trawl warps used by Japanese trawlers today is 6 × Fi (29) with a hemp core. Table 5 shows the relation between the diameter D (mm) of the trawl warps and the horse power (P) of the main engine for Japanese commercial trawlers which can be expressed approximately as:

$$D = 18 + 0.0034\, P \qquad (8)$$

During trawling operations, underwater weight of warp is much less than the tension. Accordingly, the warp in water can be considered as a straight line. On this assumption towing resistance of warps R''' (kgf) is expressed as follows:

$$R''' = \tfrac{1}{2} C_d' \rho D L V^2 \qquad (9)$$

D = diameter of warp (m); L = length of warp (m); ρ = density of sea water, i.e. 105 ($kg.s^2/m^4$); V = towing speed (m/s); C_d' = drag coefficient which is variable with the angle of attack α of the warp and also with the Reynolds Number. According to Diel (1928) the relation between the angle of attack (α) of wire rope and C_d' is as shown in fig 8 provided that the Reynolds Number is in the range from 2.5×10^4 to 7×10^4 which is generally the case in trawling. Assuming that the declination angle of the warp is equal to the angle of attack α, the value of the drag coefficient can be taken from fig 8.

As an example the resistance of a pair of trawl warps of 28 mm dia and 400 m length on a fishing ground of 110 m depth would be as follows:

$\sin \alpha = 110/400$; $\alpha = 16°$

C_d' for $\alpha = 16°$ is approximately 0.08 (fig 8)

According to Formula (9)

$$R''' = \tfrac{1}{2} \times 0.08 \times 105 \times 0.028 \times 400 \times V^2 = 47 \times V^2$$

TABLE 5. RELATION BETWEEN MAXIMUM CONTINUOUS SHAFT HORSE POWER OF MAIN ENGINE P (hp) AND TRAWL WARPS OF PRESENT JAPANESE TRAWLERS

Gross tonnage	*Maximum continuous shaft horse power of the main engine P (hp)*	*Diameter of trawl warp D (mm)*	*Breaking load of trawl warp (tf)*
314	1200	22	29.0
540	1500	24	34.6
1500	2700	26	40.6
2800	3150	28	47.1
3000	3500	30	54.0
3400	4000	32	62.0

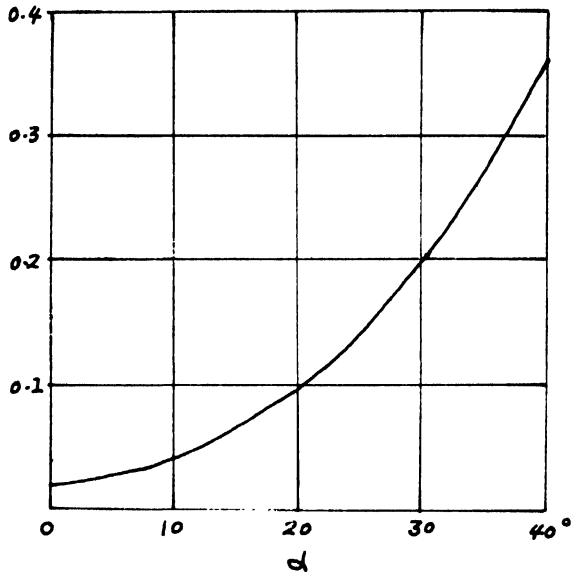

Fig 8. Relationship between drag coefficient Cd′ *and angle of attack* α *of a wire rope (after Diel 1928)*

Assuming that the towing speed (V) is 4.5 kn (2.25 m/s), R‴ is about 240 kgf for one warp and about 480 kgf for both warps.

Towing power and size of gear

Trawl gear to be towed at 4.5 kn by a trawler with a 3,150 hp main engine should have a total resistance of 13.8 tf approximately. Taking the examples of trawl net, otter boards and warps given above, the total towing resistance of this trawl gear would be:

$$R' = 11.8 \text{ tf} + 1.6 \text{ tf} + 0.48 \text{ tf} = 13.88 \text{ tf}$$

This is almost equal to the 13.8 tf and accordingly the size of the gear can be regarded as satisfactory for the towing power obtainable from a main engine of 3,150 hp.

If such calculations show a discrepancy the size of gear has to be adjusted.

In this paper a large trawler has been taken as an example. Small trawlers usually do not need a towing speed as fast as 4.5 kn and can therefore tow comparatively larger gear. The proper size of the gear is inevitably determined by the desired towing speed.

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Method of Achieving Optimum Trawling Operation

A. L. Freedman

Méthode pour l'obtention d'une operation de chalutage optimum

Le rendement de toute opération de chalutage peut être augmenté de 30 à 50 pour-cent par l'adoption d'une combinaison optimum du chalut, du poisson, du chalutier et des techniques de chalutage appropriées, sans aucune modernisation du navire et de son équipement, a l'exception de l'engin de pêche. Dans ce but, on a établi une méthode pour la conception d'un chalut optimum par le calcul de ses éléments principaux, c'est-à-dire la taille, l'ouverture, la résistance, les caractéristiques du filet, des filins, des dispositifs d'écartement, de levée et de plongée, ainsi que la longueur et le diamètre des funes. La marche à suivre comporte les phases suivantes:

(a) choix d'un prototype sur la base d'essais sur maquettes et sur le terrain, ainsi qu'en fonction de l'expérience pratique
(b) détermination empirique de la vitesse de chalutage optimum pour une espèce de poisson donnée au moyen d'essais de pêche comparatifs
(c) essais sur maquettes
(d) spécification par le calcul et dessin des éléments du chalut optimum
(e) vérification des résultats au cours d'essais en mer
(f) essais de pêche comparatifs commerciaux

Método para conseguir una manipulación optima de la red de arrastre

La eficacia de toda pesca de arrastre puede aumentarse de un 30 a un 50 por ciento logrando un equilibrio optimo entre la red, los peces, el barco y las técnicas de arrastre, sin que sea necesario modernizar la embarcación ni su equipo, exceptuado el de pesca. Para tal fin se emplea un método de diseño de la red óptima de arrastre, calculando sus partes principales: tamaño, abertura, resistencia, características de los paños, cabos, oblicuidad de las puertas, dispositivos de izado y hundimiento, y longitud y diámetro de los cables. El procedimiento consta de las fases siguientes:

(a) Selección de un prototipo, basada en pruebas de modelos y en el mar y en la experiencia práctica
(b) Determinación empírica de la velocidad óptima de arrastre para una especie determinada de peces, mediante experimentos comparativos de pesca
(c) Pruebas de modelos
(d) Cálculo, especificación y diseño de los componentes de la red óptima de arrastre
(e) Comprobación de los resultados con experimentos en el mar
(f) Pruebas comparativas comerciales de pesca

THE majority of trawlers do not utilize all their capabilities for a variety of reasons. The efficiency of operation of almost every trawler can be increased by at least 30 to 50 per cent by optimizing the technical aspect of fishing operations. This would provide for a maximum catching capacity of a trawl for a particular species of fish with complete use of available vessel power.

Until recently, such a solution was considered impossible. However, scientific research now permits a new approach.

Achievement of optimum operation represents a complex of calculations, design developments, model and field tests which are carried out in a certain sequence (Freedman, 1969), and requires a high level of scientific and technical knowledge.

This paper is rather concise because it aims at elucidating main principles and recommends certain literature. All the measures recommended are only organizational and technical in nature, i.e. it is implied that no additional capital investments or modernization of the vessel proper is required.

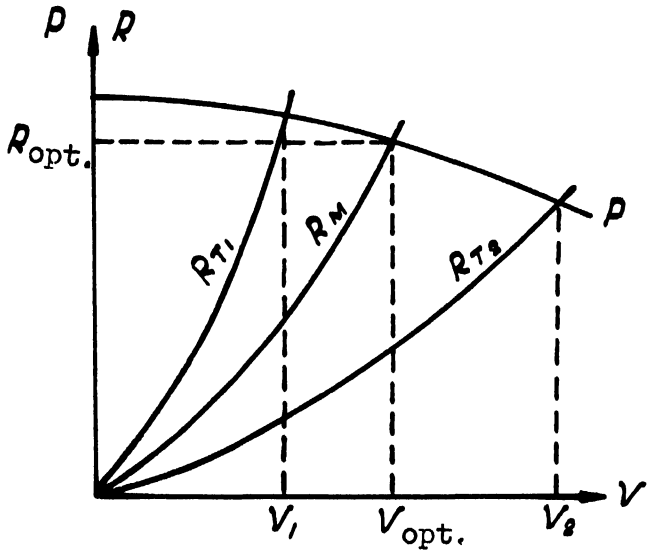

Fig 1. Correlation between towing power (P), *towing resistance* (R) *and towing speed* (v) *under various trawling conditions*

TECHNICAL PARAMETERS OF TRAWL DESIGN

The maximum dimensions, resistance, and other design parameters of a trawl should correspond to the technical characteristics of the vessel for optimum utilization of the ship.

Analysis of these factors is built on available knowledge of optimum trawling speed (V_{opt}) for every fishing object.

First, it is necessary to analyse the operation of the trawl used on a particular vessel (fig 1). Considering the trawl resistance curve (R_t) and the curve of available towing power of a particular vessel (P), for a trawl with the resistance curve R_{t1} it is clear that trawling speed v_1 is less than v_{opt}. Attempt to increase speed over v_1 would result in overloading the main engine. For a trawl with a resistance curve R_{t2} the towing power is insufficiently used at the optimum trawling speed. It means that in the first case it is expedient to use a small trawl, and in the second case a larger trawl should be utilized.

The abovementioned characteristics R_t, P, and V_{opt} should be determined according to the following methods. Trawl resistance R_t within the available range of trawling speed can be determined readily at sea using a dynamometer. Available full vessel power P_f (i.e. full traction without trawler hull resistance) can be calculated depending on the trawling speed with the help of a traction diagram for the particular vessel, and if this is not

available our method is recommended (Freedman, 1967). It is also necessary to consider the method of determining optimum speed (v_{opt}).

It is appropriate to consider whether it is more useful to take the particular trawl utilized as a base for this calculation or to select another approach.

The utility of various trawls relative to the fishing objectives is determined by comparing the results of their efficiency in actual fishing conditions. Therefore, it is advisable to select trawls utilized in the same area and for the same kind of fish. For a better comparison of design characteristics of trawls it is convenient to present them in dimensionless form, as done by M. Nomura, (1969). This permits a graphic comparison of trawls of different design and different size. Information on the trawls characteristics is valuable, namely: resistance and opening depending on the trawling speed, which can easily be compared by the corresponding index (m) indicating how many square meters of the trawl opening area F correspond to one tonf of its resistance R_t.

$$m = \frac{F}{R_t}. \tag{1}$$

This information can be obtained through experimental determination of F and R_t under field conditions or with the aid of models, which is considerably cheaper (Freedman, 1969).

Having selected the best trawl as a prototype and turning to its modernization it is necessary, first of all, to consider the optimum trawling speed for the particular fish species.

DETERMINATION OF OPTIMUM TRAWLING SPEED

The catch per haul (Q) depends on the trawl design and is characterized by the coefficient α, trawled space or volume V, and fish school density C_I.

$$Q = C_I \alpha V, \tag{2}$$

$$Q = C_I \alpha F v t, \tag{3}$$

F = trawl opening area; v = trawling speed; t = trawling time

School density C_I should be constant during the trawling period. The value α characterizing the degree of trawl perfection is often called a coefficient of the trawls absolute catching capacity. According to Ionas (1967) it can be expressed as:

$$\alpha = 1_I - \frac{B}{Fv}, \tag{4}$$

where: B—value is an approximately constant characteristic of a particular fish species.

This means (fig 2) that the trawls absolute catching capacity, i.e. the ratio of the amount of captured fish to the amount of fish which is in the zone of its operation for the trawling period, rises with the increase of trawl size and trawling speed. The same conditions also apply to the catch Q. Substituting Equation (4) into Equation (3) we obtain:

$$Q = C_I t(Fv - B). \tag{5}$$

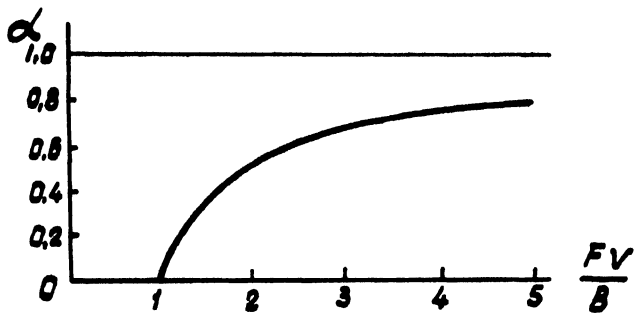

Fig 2. Correlation between coefficient of catching efficiency (α) and the technical characteristics of trawls ($\frac{Fv}{B}$)

However, the indicated trend is restricted by trawl size and speed. Nevertheless, it stresses the necessity of using the upper possible figures of these values.

In order to determinate the optimum trawling speed it is possible to use the method worked out by Rosenstein (1964).

Assuming that α depends on the trawling speed, i.e. $\alpha = f_1(v)$ and that F is also dependent of the speed, i.e. $F = f_2(v)$ we obtain, by taking into consideration Equation (3):

$$Q = C_I f_1(v) f_2(V) v t \tag{6}$$

or for a time unit

$$q = C_I f_1(v) f_2(V) v \tag{7}$$

Since $\alpha = f_1(v)$ and $F_2 = f(v)$ are determined on the basis of experience and approximations relative to V, then the optimum speed can be calculated from Equation (7) according to the conditions:

$$\frac{dq}{dv} = 0. \tag{8}$$

Two trawlers must operate similar trawls on parallel courses in order to obtain necessary data. The first one trawls at a constant speed of v_o and the second one operates at different speeds of $v_1, v_2 \ldots v_i$. Their catches will be respectively:

$$Q_o = C_I \alpha_o F_o v_o t_o,$$

$$Q_i = C_I \alpha_i F_i v_i t_i,$$

from these we obtain:

$$k = \frac{\alpha_i}{\alpha_o} = \frac{Q_i F_o v_o t_o}{Q_o F_i v_i t_i}. \tag{9}$$

Having performed a great number of comparative tows and on measuring characteristics Q, F, v, and t we can calculate the relationship by:

$$k = f(v).$$

The method of calculating this relation becomes simpler if values F are known beforehand from data of technical tests of the trawl. Then during the tests, only the records of catches, speed, and time have to be determined.

Assuming that α_o of the standard trawl (reference model) is a certain constant from Equation (9) we obtain:

$$\alpha_i = k\alpha_o = kC_2.$$

Substituting into (7) we obtain

$$q = C_1 C_2 k f_2(v) v$$

or

$$q = Ck f_2(v) v. \quad (10)$$

Having differentiated this equation according to v it is possible to determine at what speed we can get the maximum catch for a time unit q, i.e. to determine the optimum trawling speed for the particular fish and given trawl. Further calculations of the optimum trawl and its interaction with the vessel are carried out at exactly this speed (V_{opt}). These experiments do not involve additional expenditures since they are carried out during fishing. However, the value of the data obtained is extremely high.

Technical characteristics of a prototype trawl

To perform required calculations for a particular trawler it is necessary to have complete information about the prototype technical characteristics. It is possible to get it most conveniently and cheaply by testing a physical model of the prototype-trawl in a suitable water pool using a little boat of 20 to 30 hp. In this case the scale of the models will be about $\frac{1}{4}$ to $\frac{1}{6}$.

Testing and improvement

It has been proven by experiments that the difficulties of obtaining complete similarity in modelling a trawl (Freedman 1969) which include Reynold's criterion and Froude's generalized criterion can be radically simplified. In this connection the generally accepted notions of specific linear dimension have been revised. It was found that a reasonably proportioned model net may be considered as an invariant of the mesh system forming it, i.e. its resistance does not depend on the order in which the net meshes (or separate nebbing parts) are arranged.

It can be shown that for the approximate similarity of a specific trawl type it is possible to consider not the overall net dimension but its mesh size and in particular the twine diameter. In such approach the values of the similarity criteria for the model and fullsize net are essentially the same. At the same time we obtain the opportunity of radically improving the method of calculating fishing gear resistance by summing up its parts.

Approximate modelling with due regard of the scale effects provides for acceptable accuracy of tests and recalculation of the results for a fullsize net. This is achieved through revealing the physical conditions of movement where the influence of Reynold's criterion and Froude's generalized criterion is small. For these physical conditions of movement the similarity is provided with a sufficient accuracy by observing Newton's rule Ne = idem in the form of:

$$\frac{qa}{\rho d l^2 v^2} = \text{idem}, \quad (11)$$

and the equality rule of the relative net areas

$$F_0 = \frac{d}{a} \frac{1}{u\, u_2} = \text{idem}, \quad (12)$$

where: q = acting force irrespective of its origin (kgf)
a = mesh bar (mm)
ρ = medium density (kg sec^2/m^4)
d = twine diameter (mm)
Ll = specific model dimension (m)
v = specific speed (m/sec)
u_1 and u_2 = coefficients of the net hangings.

Modelling according to conditions Ne = idem and F_o = idem gives an opportunity for selecting at random the similarity scales, i.e. the model dimensions and its towing speed which allow convenience in the conduct of experiments and determining the technical characteristics of experimental gear. Condition F_o = idem makes it possible to choose at random the netting for the model and, that especially simplifies the matter, permitting making the model from the same netting which is used for a full-size trawl. The results of the model tests, provided that they have been performed correctly, are as reliable as the results of field tests. The accuracy of model tests is increased as the number of measurements increases. This is more difficult to obtain with full scale gear under field conditions. Costs of model tests are considerably lower.

However, an increase or decrease of the prototype trawl dimension is not the best solution. Though the prototype-trawl has been selected as best of the used trawls it is necessary to determine whether its hydromechanical characteristics can be improved, i.e. to provide for a larger opening at less resistance. This work cannot be carried out according to any single method. Here only some constructive ways can be indicated which lead to the objectives, i.e. increasing the active forces of the rigging (shearing, hauling, floating, and sinking means), decrease of the rigging resistance, utilization of nets with increased mesh size, application of net materials with smaller coefficient of hydrodynamic resistance.

After fishing the modified prototype it is necessary to perform a comprehensive test of its model (or of the full-size version) in order to determine the effectiveness, as well as to determine more precisely the trawls characteristics. The next stage of the work consists in correlating the prototype-trawl characteristics with towing power of the vessel at the optimum trawling speed.

Calculation of optimum trawl characteristics

The determination of the optimum trawl is performed by taking into consideration the fact that it is similar to the selected one and also probably to the improved prototype. Based on this condition, the correspondence between their characteristics is determined by Equation (11) which is presented for the sake of simplicity as:

$$\frac{C_q C_a}{C_\rho C_d C_l^2 C_v^2} = 1, \quad (13)$$

where symbol C denotes the ratios (scales) of corresponding physical values, for instance, the scale of the acting forces:

$$C_q = \frac{q_m}{q_f}$$

where index "m" is attributed to the model which implies

in this case a newly designed trawl, while index "f" denotes a full-size trawl, i.e. the prototype-trawl.

In order to provide for a required strength of the new trawl netting (9) use is made of the following condition:

$$\frac{C_d}{C_v}\sqrt{\frac{C_\sigma C_{u_2}}{C_n C_a C_l C_{u_1}}} = 1, \tag{14}$$

where $C\sigma$ = relation breaking load of the twines

C_n = safety factor for twine strength.

If it is understood that active forces q are trawl resistance R, then from the joint solution of Equations (13) and (14) we obtain:

$$C_R = C_l^{5/2} C_v^3 \sqrt{\frac{C_n C_{u_1}}{C_\sigma C_a C_{u_2}}}, \tag{15}$$

from which it is possible to determine any linear dimension of the optimum trawl l_m using the expression

$$L_m = L_f^{5/2}\sqrt{\frac{C_R}{C_v^3}}\sqrt{\frac{C_\sigma C_a C_{u_2}}{C_n C_{u_1}}} \tag{16}$$

All the values included in the right part of Equation (16) are either known or selected by a designer; values L_f are known from the drawing of the prototype-trawl; speed scale C_v is a relation of the optimum trawling speed obtained from the experiments $v_{opt} = v_m$ against prototype trawling speed v_f; scale of resistance forces C_R is a relation of available power $P_{av} = R_m$ (at v_{opt}) against prototype resistance R_f; the remaining scales are selected by the designer.

We consider the mesh bar scale C_a as a relation of corresponding mean characteristics a_{mean} for the trawl net as a whole

$$C_a = \frac{a_{mean.\,m}}{a_{mean.\,f}}, \tag{17}$$

Whereupon

$$a_{mean} = \frac{\sum_{i=1}^{i=n} a_i F_i}{\sum_{i=1}^{i=n} F_i}, \tag{18}$$

where F_i is an area of the corresponding net part with mesh bar a_i. Value F_i is still unknown for the optimum trawl to be designed, however since it is similar to the prototype we have the following condition for every trawl

$$\frac{F_i}{\sum_{i=1}^{i=n} F_i} = \text{const},$$

therefore, it is possible to use values F_1 of the prototype in the calculation $a_{mean.m}$.

Correspondingly, under the thread diameter scale C_d we have the relation

$$C_d = \frac{d_{mean.\,m}}{d_{mean.\,f}}, \tag{19}$$

whereupon

$$d_{mean} = \frac{\sum_{i=1}^{i=n} d_i L_i}{\sum_{i=1}^{i=n} L_i}, \tag{20}$$

where L_i is the twine length for the i-part with diameter d_i. As stated above it is possible to use values L_i of the prototype corresponding parts in the calculation of d_{mean} of a new trawl. In order to determine the mesh bar in the trawls individual parts it is advisable to apply the method developed by S. B. Gyul'badamov (1958).

Obtaining scale C_l from Equation (16) it is not difficult to calculate all the linear characteristics of the optimum trawl and design it. The calculations can be checked tracing on fig 1 the optimum trawl resistance curve R_m which should intersect traction curve P at optimum trawling speed v_{opt}.

In order to determine the characteristics of the ropes used for rigging and towing the trawl (e.g. headlines, legs, leadlines, bridles, warps) a method is suggested, the principle of which consists in applying the same power scale C_R as that for the whole trawl:

$$C_F = \frac{C_n C_l}{C_\sigma}, \tag{21}$$

where: F = rope section area;

n = total safety factor;

σ = breaking load of rope.

The trawl rigging has some forces which have a defined value and direction; therefore, designing any device requires the same scale C_R as for the trawl. The general rule consists in the fact that

$$q_m = q_f C_R \tag{22}$$

When the corresponding force q_m is determined, the designer selects the most effective design and calculates the dimensions of the particular device. For example, in designing an otter board its shearing force (lift) can be determined as

$$R_{ym} = R_{yf} \cdot C_R, \tag{23}$$

the required area can be found from

$$F_m = \frac{R_{ym}}{C_y \frac{\rho v^2}{2}}, \tag{24}$$

where C_y is the shearing force coefficient of the design which has been selected for the optimum trawl. If the prototype-board drawings are available it is easy to determine the linear scale C_{lg}, which extremely simplifies the drawing of the new board, including the determination of the coordinates of the points to which the warp and bridle will be fastened:

$$C_{lg} = \sqrt{\frac{F_m}{F_f}}. \tag{25}$$

Thus, applying the indicated methods it is possible to carry out a complete calculation of all the dimensions of the trawl net and its separate parts, all the ropes and all the rigging elements, to prepare the drawings and technical documentation, and to determine in advance the resistance and opening of the optimum trawl for a particular vessel.

CHECKING RESULTS

A full-size prototype-trawl, its model or the model of the improved prototype-trawl may be used as a "standard". The accuracy of re-calculation of the characteris-

tics is higher in the first case (i.e. less difference in absolute quantities); the smaller the models the lower the re-calculation accuracy. Therefore, it is advisable to check the calculated results by performing technical tests of the designed optimum trawl under sea conditions. Then, comparative fishing tests of this trawl are carried out on the fishing grounds in order to determine its relative catching capabilities as compared with the prototype (fig2). The tests are performed with two vessels by parallel trawling and comparing 24-hour catches.

It may seem that a practical application of substantiating the trawlers optimum operation in the course of fishing is very labour-consuming, however, the spent labour will be paid off by the fact that without additional capital investment, the catch is increased, labour productivity is raised, the technical operation of the trawler engine is improved, and the vessels overall economic indices are increased.

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Note sur l'Augmentation des Possibilités de Capture dans la Pêche du Hareng au Chalut

A. Maucorps, M. Portier

Note on the increase of catching performance in herring trawling

During recent years, a considerable development has taken place in fishing techniques and equipment. This development has lead to an increase of the catching ability of modern vessels; an increase which cannot be measured easily. With regard to herring fisheries in the North Sea, however, an attempt has been made to evaluate the areas exploited by bottom trawl, semi-pelagic and pelagic trawls. Lastly, the chances of finding a fish school have been greatly increased by the application of horizontal scanning, as shown by a theoretical estimation of surface areas scanned by an echosounder and a sonar respectively. The estimation of the increase in catching possibilities obtained by combining the new means of detection and gear used on board modern powerful vessels is difficult, due to the depletion of stocks resulting from their over-exploitation.

Nota sobre el aumento de las posibilidades de captura en la pesca del arenque con red de arrastre

En estos últimos años, el material y las técnicas empleadas en la pesca han experimentado una evolución considerable. Estas modificaciones han aumentado el poder de pesca de los barcos modernos en proporciones difíciles de calcular. A pesar de ello, por cuanto se refiere a las pesquerías de arenque del Mar del Norte se han podido evaluar las extensiones explotadas por una parte con redes de arrastre de fondo y por otra con redes de arrastre pelágicas o semipelágicas. Por último, la aplicación a la pesca de los aparatos de detección horizontal ha permitido aumentar considerablemente las posibilidades de localizar los bancos de pescado, como lo demuestra una estimación teórica de las extensiones exploradas por una ecosonda detectora y por un sonar, respectivamente. La disminución de las poblaciones, unida a la explotación excesiva de la mismas, hace difícil une evaluación del incremento de las posibilidades de captura permitida por la combinación de los nuevos medios de detección y los artes de pesca empleados a bordo de las potentes embarcaciones modernas.

Au cours de ces dernières années la pêche du hareng, particulièrement en Mer du Nord, a connu de très grands bouleversements qui se sont traduits par une augmentation de l'efficacité des techniques de capture.

Il nous a semblé intéressant de faire, dans cette courte note, une étude plus particulière de l'évolution de la pêche du hareng bouvard en s'attachant non seulement aux transformations effectuées sur les chaluts dans le but d'en accroître la surface pêchante, mais aussi aux conséquences qu'out entraînées l'apparition, puis la généralisation, des nouveaux moyens de prospection.

ETUDE COMPARATIVE DES ENGINS DE PECHE

Si l'on estime qu'il existe une relation étroite entre le pouvoir de pêche et la puissance ou le type du navire, le passage des chalutiers latéraux de 750–1.000 CV à des bateaux pêchant par l'arrière, dont la force motrice atteint et même dépasse 2.000 CV, constitue un phénomène capital. En effet, le chalutage par l'arrière permet de gagner un temps appréciable lors des manoeuvres de filage et de virage. De plus, dans le cas des chalutiers

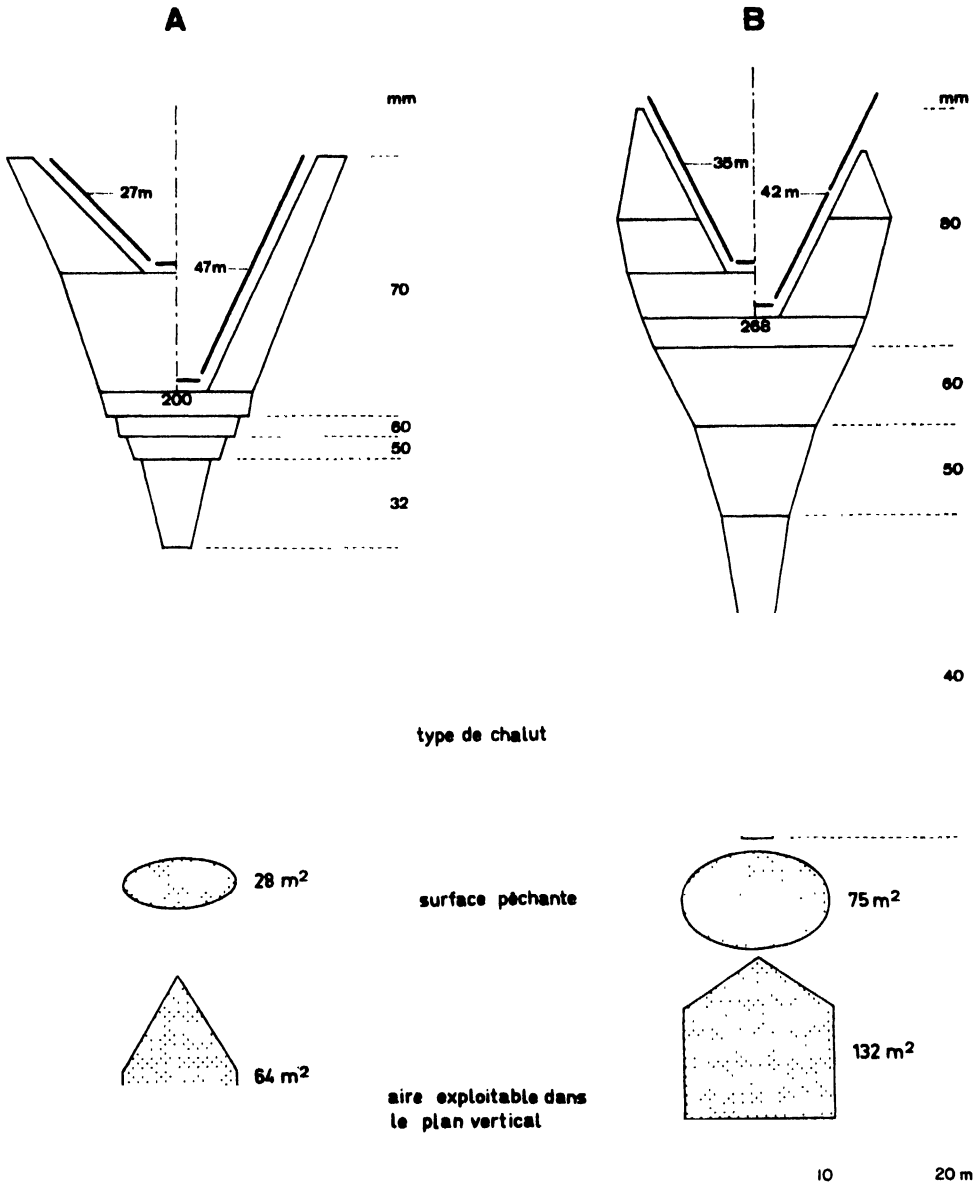

Fig 1A. Chalut de fond 27/47. En regard du plan du filet, on a indiqué à la même échelle: la surface pêchante du chalut au niveau du carré de ventre: l'aire exploitable estimée comme la somme de la surface pêchante et de l'aire couverte par le plateau élévateur
Fig 1B. Chalut semi-pélagique 35/42. Comme pour le chalut de fond 27/47, on a représenté, à la même échelle que le plan du fillet, la surface pêchante du chalut et l'aire exploitable estimée

à rampe, ce gain peut être encore plus prononcé s'ils ont la possibilité de hisser d'une seule portée, à l'aide d'un palan frappé en tête de cheminée, ou sur l'arrière de la passerelle, des charges allant jusqu'à 50 tonnes et plus. Enfin l'amélioration des conditions de sécurité et de tenue à la mer de ces navires leur permet souvent de travailler plus longtemps que les chalutiers latéraux, en cas de mauvais temps.

Une autre amélioration, importante par les conséquences qu'elle a eues et par les développements qu'elle a suscités, concerne les matériaux servant à la construction des engins de pêche. En effet, l'emploi généralisé des nouvelles fibres textiles synthétiques dans la confection des alèzes a permis d'accroître la résistance des fils tout en diminuant leur diamètre. Il a ainsi été possible d'augmenter les dimensions des chaluts.

Ces différents changements, tant dans la conception des navires que dans celle des engins qu'ils utilisent, ont amené une augmentation incontestable du pouvoir de pêche.

Il semble bien difficile, sinon impossible, de chiffrer avec précision cette évolution. On peut cependant, à propos du cas du hareng de la Mer du Nord, examiner les modifications intervenues dans le pouvoir de capture des chaluts utilisés par les bateaux français qui pratiquent la pêche de cette espèce.

Le chalut de fond

Il y a moins de 10 ans, les bateaux harenguiers utilisaient pratiquement tous le chalut de fond du type 27/47. Ce filet comporte un important recouvrement de dos et présente un périmètre au niveau du ventre de 400 mailles

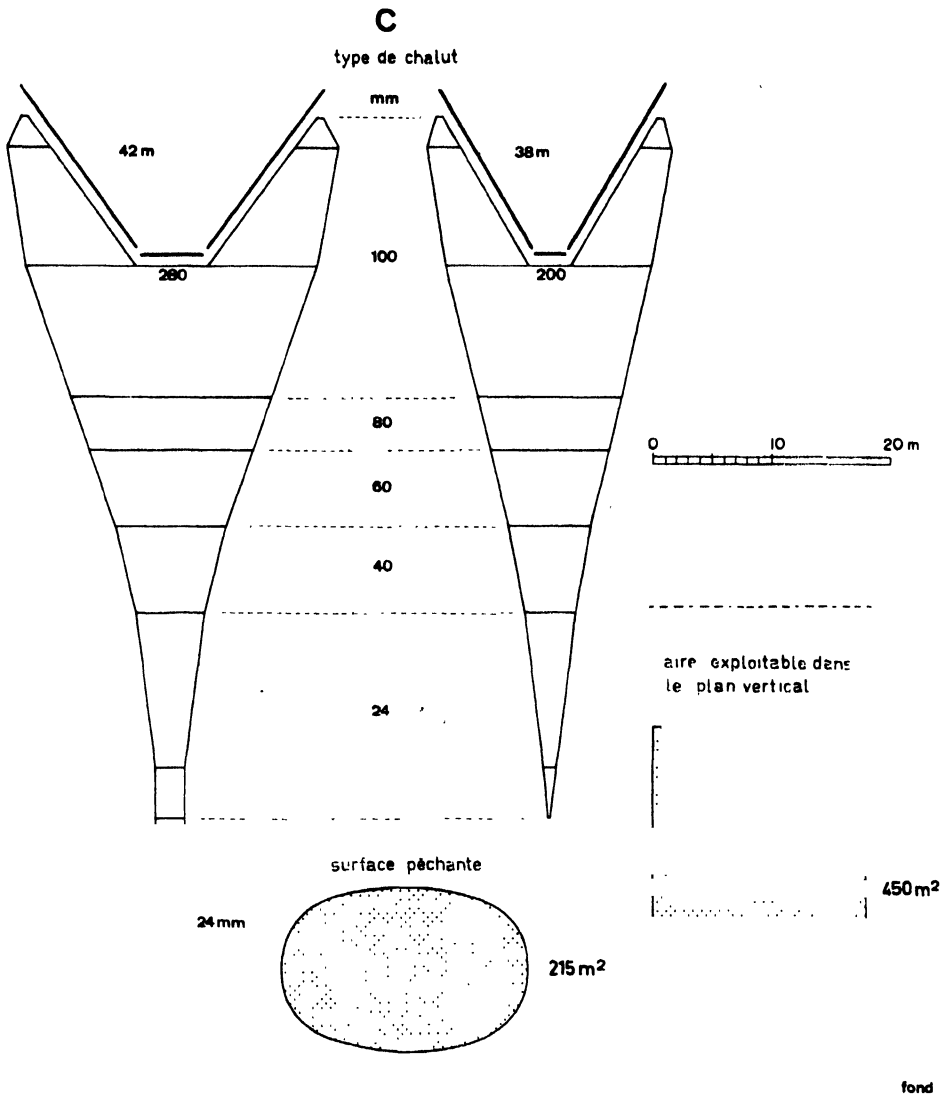

Fig 1C. Chalut pélagique 42/38. A la même échelle que celle du plan du filet on a dessiné: la surface pêchante au niveau des carrés. L'aire exploitable couverte par le chalut dans ses évolutions entre 10 m de la surface et 3 m du fond (par fonds de 40 m)

de 70 mm de côté (5″ ½ stretched). L'ouverture verticale de ces filets, mesurée au netzonde dépasse rarement 3,50 à 4,00 m (12 à 13 ft). Pour augmenter cette ouverture assez faible d'une part et pour améliorer les chances de capture d'un poisson souvent décollé du fond d'autre part, ces chaluts étaient généralement utilisés avec un et le plus souvent deux plateaux élévateurs. Dans ces conditions, on peut estimer, en assimilant l'ouverture au niveau du ventre à une ellipse et en ajoutant à cette surface celle d'un triangle dont le sommet représente le premier plateau élévateur (fig 1A), que l'aire exploitable par un tel chalut dans le plan vertical est d'environ 64 m² (690 ft²).

Le chalut semi-pélagique

Traitons maintenant de la même façon le cas du chalut semi-pélagique, dont l'emploi s'est généralisé depuis 1965, et prenons par exemple un chalut de 35 m (115 ft) de corde de dos et de 42 m (137 ft) de bourrelet utilisé par des bateaux de 900 à 1.000 CV. C'est un chalut dont le recouvrement de dos est très faible et dont le périmètre au niveau du ventre est égal à 536 mailles de 80 mm (6⅓ in). Dans les conditions normales d'utilisation ce filet travaille sur le fond; toutefois, avec un gréement approprié, son ouverture verticale mesurée au netzsonde est d'environ 8 m (26 ft) et il est le plus souvent muni d'un plateau élévateur.

On estime alors qu'il couvre une surface verticale de 132 m² (1,420 ft²) environ (fig 1B); en conséquence ses possibilités de capturer le poisson, en particulier lorsqu'il est légèrement décollé du fond, sont augmentées par rapport au chalut.

Le chalut pélagique

Les chaluts pélagiques utilisés par petits fonds sur les concentrations denses de harengs entre deux eaux ont

des dimensions relativement restreintes par rapport à ceux employés lorsque le hareng se trouve plus dispersé ou par des profondeurs plus grandes. Dans le sud de la Mer du Nord, les bateaux d'une force motrice comprise entre 850 et 1.100 CV remorquent des chaluts à ouverture rectangulaire de 42 m (137 ft) de ralingues supérieure et inférieure et de 38 m (125 ft) de ralingues de côté. Leur ouverture verticale est de 11 à 12 m (environ 38 ft) et on peut en estimer la surface pêchante à 215 m² environ (2,314 ft²).

Ces chaluts employés avec des panneaux hydrodynamiques compensent leur surface pêchante relativement faible par des grandes possibilités évolutives. Ils peuvent en effet prospecter, par des fonds de 40 m (131 ft), une tranche d'eau comprise entre 10 m (33 ft) de la surface et 3 m (10 ft) du fond (fig 1C). Ceci leur permet d'exploiter une aire d'environ 450 m² (4,844 ft²).

Si on admet que la vitesse de traîne pour ces 3 types de chalut est restée sensiblement la même (3,5 à 4 noeuds) et si l'on se base sur l'aire exploitable, dans le plan vertical, du chalut de fond (65 m² = 700 ft²) on se rend compte que celle du chalut semi-pélagique représente environ deux fois cette surface et celle du chalut pélagique approximativement sept fois

Peut-on alors, dans le cas de la pêche d'une espèce qui évolue la surface et le fond, estimer que les chances de capture sont multipliées par ces mêmes coefficients? Le problème est sans aucun doute beaucoup plus complexe, car il est nécessaire de tenir compte du comportement du poisson dont la densité paraît être plus forte quand il est rassemblé sur le fond et les évolutions plus marquées dans certaines conditions, notamment selon son stade sexuel, la turbidité des eaux, la période de la journée ou la saison.

ETUDE COMPARATIVE DES ENGINS DE DETECTION

Parallèlement l'évolution du pouvoir de pêche des navires, durant ces 20 dernières années, a été marquée par un autre phénomène qui a affecté de manière fondamentale le caractère de la pêche et les chances de capture des chalutiers. Il s'agit en effet de l'introduction et du développement tout d'abord de la détection des bancs de poissons puis plus récemment de la recherce active de ces concentrations.

Le sondeur détecteur

Le premier type d'appareil, utilisé sur les chalutiers même de faible tonnage, est le sondeur détecteur à base émettrice fixe. Le faisceau ultra-sonique émis s'ouvre (transversalement par rapport à l'axe du navire) sous un angle moyen de 15° avec plus ou moins 5° suivant les fréquences choisies et les dimensions de la base émettrice; si bien que la bande de terrain explorée par 40 m (131 ft) de fond, par exemple, aura une largeur de 10 à 20 m (33 à 66 ft), la longueur dépendra essentiellement de la vitesse et de la durée du déplacement du chalutier. Si nous prenons comme sonde de référence seulement 40 m (22 fm) c'est que cette valeur correspond à la profondeur moyenne de la zone des frayères dans le sud de la Mer du Nord et en Manche orientale.

Nous pouvons donc estimer qu'un chalutier à la vitesse moyenne de 6 noeuds balaye en une heure une zone d'environ 170.000 m² (203,320 yd²) avec ce type d'appareil.

Le sonar

L'introduction plus récente d'un détecteur horizontal à faisceau orientable tant en gisement qu'en site, appelé asdic ou sonar, a modifié de façon fondamentale le rapport existant entre l'abondance d'un stock et la probabilité de capture par un chalutier des poissons constituant ce stock.

La portée du sonar, ou distance maximale à laquelle un banc de poissons donne un écho identifiable, est fonction en premier lieu des paramètres électroniques choisis lors de la conception de l'appareil telles que la fréquence, la durée de l'impulsion, la largeur du faisceau. Cependant, en plus de ces facteurs que l'on peut qualifier d'internes, des facteurs externes peuvent modifier la portée pratique du sonar comme, par exemple, la tranquilité en surface des eaux, la nature des fonds ainsi que la plus ou moins grande homogénéité du milieu aqueux qui se traduit par l'absence ou la présence de fronts thermiques, de thermoclines et de couche profonde diffusante (D.S.L.).

Afin de pouvoir comparer les possibilités de détection d'un sondeur détecteur et celles d'un sonar, nous avons considéré que les facteurs externes étaient suffisamment peu marqués pour ne pas entraver la propagation du faisceau du sonar. C'est ainsi que malgré une sonde relativement faible (40 m = 22 fm), nous pouvons admettre qu'un banc de poissons est repérable à une distance de 1.000 m (environ 549 fm).

L'aire pratique couverte par le faisceau du sonar, dans un balayage automatique, peut être, dans une certaine mesure assimilée à un rectangle dont la largeur est de 2 fois la portée considérée et la longueur est fonction du déplacement du navire. Ainsi, à la vitesse de 11 noeuds, utilisée en prospection au sonar, ce déplacement est de 20 km (21,873 yd) en 1 h, ce qui donne avec une portée de1.000 m une aire totale d'environ 40.000.000 m² (48,192,771 yd²).

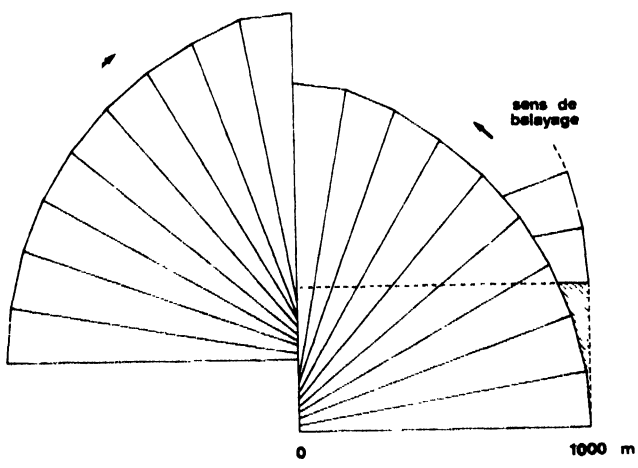

Fig 2. Aire prospectée au sonar avec balayage de bord à proue. Vitesse du navire—11 noeuds. Portée = 1,000 mètres. Durée d'une séquence complète de balayage = 90 secondes environ. La partie hachurée correspond à une zone marginale non explorée

Cette estimation correspond donc grossièrement à l'aire utile couverte par le sonar; elle fait abstraction des recouvrements successifs du balayage et elle ne tient pas compte des zones marginales non explorées par le faisceau d'ultra-sons. Ces zones, d'importance plus ou moins grande, dépendent de la vitesse du navire, de la portée sélectionnée et du type de balayage automatique choisi, bord à bord simple, bord à bord avec retour sans détection, ou bord à proue. Avec une fréquence de balayage relativement rapide, les zones non explorées sont relativement faibles et peuvent être négligées (fig 2).

APPLICATION

On peut s'étonner du choix qui a été fait des vitesses moyennes, soit 6 noeuds pour le chalutier équipé d'un sondeur vertical et 11 noeuds pour celui utilisant un sonar. Mais les deux méthodes de recherche (et par suite de pêche) sont fondamentalement différentes.

En effet, le chalutage traditionnel au hareng sous-entend que le chalutier, dès son arrivée sur les frayères ou dès qu'il détecte une première tache, met son chalut à l'eau et procède en même temps à la détection et à la pêche. Son traict dure 1 à 2 heures à une vitesse qui est d'environ 4 noeuds. Aussi, en tenant compte des périodes de prospection comprises entre 8 ou 10 noeuds, on peut estimer que la vitesse moyenne de ce chalutier sur les lieux de pêche est de l'ordre de 6 noeuds.

Très différente est la méthode de pêche du hareng au chalut semi-pélagique et pélagique avec détection horizontale. Dans ce cas la majeure partie du temps est consacrée à la recherche des bancs à l'aide du sonar. Cette prospection se fait à une allure soutenue de 11 à 12 noeuds et c'est seulement lorsqu'un banc est repéré que le chalut est filé; son immersion est réglée quand la tache apparaît sur l'échogramme du sondeur vertical. La capture est enfin confirmée grâce au sondeur de corde de dos. Le passage du chalut dans la tache peut être doublé ou triplé suivant l'estimation qu'a le patron de la densité de cette détection. Le chalut est alors viré et la pêche est amenée à bord. Le temps de chalutage est donc réduit au minimum.

Augmentation du pouvoir de capture

Il est bien entendu que l'estimation des aires de balayage n'a qu'une valeur de référence. En effet, elles ne doivent pas être prises comme valeur absolue des aires couvertes, en raison notamment de la façon de travailler, qui est particulière à chaque capitaine de pêche, des phénomènes hydrologiques que nous avons signalés ou encore des variations de la nature des fonds. La présence de ridins ou de zones rocheuses irrégulières risque bien souvent et en particulier dans la région du Pas-de-Calais, de limiter la portée pratique du faisceau du sonar ainsi que sa possibilité de discrimination. Des bancs de poissons peuvent en effet être masqués par la réverbération de ces accidents du terrain.

Toutefois, la comparaison des aires théoriques de balayage met en évidence l'extraordinaire disproportion qui existe entre les possibilités de repérage des chalutiers équipés de l'un ou de l'autre de ces appareils de détection, 170.000 m^2 (203,320 yd^2), dans un cas contre 40.000.000 m^2 (47,840,000 yd^2) dans l'autre, soit environ 235 fois plus.

CONCLUSION

Si l'on considère l'évolution de la pêche du hareng au cours des dix dernières années on constate que l'on est passé du chalutage de fond avec sondeur vertical, au chalutage semi-pélagique et pélagique dont l'emploi est maintenant inséparable du sonar.

Ainsi que nous l'avons montré dans cette courte note, cette transformation a entraîné une augmentation importante du pouvoir de pêche des engins ainsi qu'un accroissement considérable des possibilités de détection. Il est donc bien évident que l'efficacité d'un chalutier moderne est considérablement supérieure à celle d'un bateau de même puissance des années 1950 à 1960. Cependant, il semble extrêmement difficile de chiffrer ces changements intervenus dans la pêcherie du hareng au chalut car, parallèlement, le stock de hareng, qui a subi surtout dans le sud de la Mer du Nord le contre-coup d'une exploitation très forte, ne peut fournir de claires indications sur les variations des captures par unités d'effort.

Behaviour Patterns of Different Herring Stocks in Relation to Ship and Midwater Trawl

H. Mohr

Les modes de comportement de differents stocks de hareng en relation avec le bateau et le chalut pelagique

L'efficacité du chalutage pélagique est influencée par les relations qui existent entre la formation des bancs, les migrations diurnes et les réactions du poisson au bateau et à l'engin de pêche. Au cours du développement du chalutage pélagique, pendant la dernière decade, un grand nombre d'observations sur ces modes de comportement ont été recueillies sur des navires de recherche et des chalutiers allemands au moyen d'un équipement d'échosondage. Les essais sur le hareng concernent la plupart des stocks de la Mer du Nord et des eaux adjacentes, ainsi que les stocks atlanto-scandinaves et ceux du Nord-Ouest Atlantique. Les types de formation en banc et les particularités des migrations diurnes du hareng sont classifiés en fonction du chalutage pélagique. Ils constituent des indications sur la condition physiologique et le caractère de la réaction, laquelle peut varier considérablement dans le temps et entre les différents stocks. Les règles des réactions, établies dans ce document, s'appliquent à tous les stocks mentionnés à l'exception du groupe atlanto-scandinave. Les difficultés qui se présentent pour la capture des harengs de ce dernier groupe à certaines périodes proviennent d'une puissance de nage et d'une vivacité très grandes. Les conclusions tirées des observations effectuées sur le comportement du hareng pendant la capture ont eu des conséquences directes importantes sur la fabrication des chaluts modernes et ont influencé d'une manière indirecte la taille et la puissance des chalutiers.

Caracteristicas de comportamiento de las diferentes poblaciones de arenques en relación con los barcos y la pesca al arrastre entre dos aguas

En la eficacia de la pesca al arrastre pelágica influye la interrelación que existe entre los cardúmenes, las migraciones diurnas y las reacciones de los peces a los barcos y artes. Durante el desenvolvimiento de la pesca al arrastre entre dos aguas, en el último decenio, se reunieron muchas observaciones sobre estos tipos de comportamiento por medio de equipo de sondeo acústico a bordo de arrastreros alemanes y de investigación. Los ensayos sobre el arenque abarcan a casi todas las poblaciones del Mar del Norte y aguas adyacentes, las poblaciones del Atlántico noroccidental y las de la parte escandinava del Atlántico. Se clasifican los tipos de cardúmenes y las características de las migraciones diurnas de arenque con respecto a la pesca al orrastre pelágica. Representan indicaciones del estado fisiológico y de la disposición a la reacción, que varía ampliamente por lo que se refiere al tiempo y de unas a otras poblaciones. Las reglas de las reacciones, establecidas en este estudio, son aplicables a todas las poblaciones mencionadas con excepcion del grupo de la parte escandinava del Atlántico. Las dificultades que se encuentran para capturar estos arenques en ciertas fases se deben a su extrema viveza y a su capacidad natatoria. Las conclusiones deducidas sobre el comportamiento de los arenques observados durante la captura tuvieron importantes consecuencias directas en la construcción de artes de arrastre modernos e indirectamente influyeron en el tamaño y potencia de los arrastreros.

SINCE midwater trawling and purse seining have been intensified questions of fish behaviour have become more and more urgent. Especially herring proved one of the most skittish and agile species—its reactions often unpredictable. Gear and methods which were quite successful under certain conditions, failed completely at other times or locations. Reason was different behaviour in the various stocks and changes in their reactions due to season and physiological state.

More than any other exploited marine fish, herring are split up into numerous races which differ in size and behaviour. In the NE Atlantic already four main groups are distinguished, which segregate again in a number of stocks. The principal European fisheries are based on the "oceanic" group (five stocks) and the "shelf" group (six stocks). The first are large sized fish and mainly winter-spring spawners, the latter are fish of moderate size which spawn during summer and autumn (Parrish and Saville, 1965). Since a few years herring stocks of the NW Atlantic, off New England and on the Georges Bank, have become very important for a number of European countries. These fish resemble in size and behaviour the European shelf-group. The instrinsic rhythms of spawning and migration are timed and modified by hydrographic conditions and thus vary widely. To make things more complex, different stocks occur often in the same area and even form mixed schools.

To consider all these circumstances for practical fisheries is too complicated and almost impossible because of the constant variations. For practical purposes knowledge has to be restricted to factors relatively independent of a certain stock, and to indications of the disposition of fish ("motivation") which can be observed during the fishing operation, such as schooling patterns and diurnal migration features, which are an expression of the physiological condition and motivation of the fish. Reactions to ship and gear can be observed to some extent on modern equipped ships.

The interdependence and interaction of these three complexes of behaviour are decisive for success or failure. With herring, according to our experience, there is no significant difference between stocks except the oceanic herring. The following observations and conclusions are rules rather than laws. There were in each case more or less inexplicable exceptions.

STOCKS OBSERVED AND METHODS EMPLOYED

The statements in this paper are based on observations made in connection with the development of pelagic trawling in the Institut für Fangtechnik within the last ten years. The main object of these trials was herring which was caught in the course of years on different grounds of the North Sea, English Channel, Irish and western English waters, Skagerrak, Norwegian coast, Faroes, Iceland, Georges Bank and New England coast.

Observations on their behaviour were made by echo sounding equipment according to the state of development at the respective time, i.e. at first vertical sounders only, later combined with netsonde and sonar. On research vessels more sophisticated devices were employed. Since 1965 the "multi-netsonde", developed and improved in the following years by Schärfe (1969), was used extensively. This device allowed to switch on alternatively up

to seven transducers fixed at different positions of the gear. During one cruise of *FRV W. Herwig* a "panorama sonar" could be used to some extent, while it was tested by the producers for its applicability in fisheries. With this apparatus sectors of varying size, horizontally or vertically, could be scanned and the echoes were shown on a cathode ray tube. Under suitable sea conditions sometimes a motorized rubber boat equipped with an echo sounder was used to examine the gap between trawler and trawl.

BEHAVIOUR OF HERRING

Commercial herring fishing depends on their grouping. If the fish is randomly orientated, these groups are conventionally called "aggregations"; if polarized and tightly packed they form "schools" in the strict sense of the word (Breder, 1959; Shaw, 1967). The kind of grouping is decisive for capture, not only because of different density but also because of different reactions to ship and gear. Aggregations of the same type had similar reactions, no matter to which stock they belonged.

These patterns of aggregating were found typical for herring (in brackets is given appearance in the vertical sounder's echo chart).

(a) Diffuse widespread aggregations (grey layers or clouds). This type is characteristic for relatively passive phases in the life cycle of herring and is most pronounced during hibernating in deep water. The horizontal distribution of these layers may extend for several square miles. The vertical distribution reached from about 20 m (Skagerrak) to 150 m (East Iceland Current). The density usually is in the range of 0.1 to 1 fish/m^3 (Scherbino and Truskanov, 1966; Mohr, 1967).

With larger midwater trawls (opening 20 m or more in both dimensions) these layers usually are easy to fish. Disturbances due to the vessel could not be observed. Reactions caused by the gear are restricted in time and space to the proximity of the source of the disturbance and range from a few to some ten metres. The effect of otter boards and bridles is even considered to be favourable, because they herd and concentrate the fish into the path of the trawl. In the net mouth the fish usually keep a distance of 6 to 8 m from the frame ropes, thus a net opening of less than 12 m often does not catch any fish. The larger the dimensions of the opening, the better the rate between actual opening and "efficient" opening (actual opening less a marginal zone of about 6 m). The towing speed is not decisive for large trawls and a reduction to about 2 kn is sometimes even favourable, because then the turbulences decrease and the fish may be "outwitted" (Schärfe, 1968).

An exception to this rule is the Atlanto-Scandian herring when the migrating schools of pre-spawners have dispersed to layers at the Norwegian coast. This herring is still very alert and, favoured by their large size (and speed), escape from the gear even when towed at 3.5 to 4 kn.

The temporary layers which rise from other types of aggregations during the night at the surface are considered in connection with the diurnal migrations.

(b) Concentrated stationary aggregations, mostly in contact with the bottom (black steeples, towers and blocks). These types of aggregations are significant for the shelf—and New England—herring in the pre-spawning and spawning period. Pre-spawners regularly show a diurnal vertical migration, spawners often rest during day and night. The first are rather skittish opposite the gear and smaller groups often succeed to escape. In the net opening they try to keep a distance of some metres from the frame ropes too, but in large and dense aggregations this is not always possible because the fish handicap each other and then the whole net opening is blacked out in the recorder of the netsonde. The towing speed has to be in the range of 3.5 kn for the medium sized shelf and New England herring. As the spawning time approaches the more sluggish and indolent the fish become. At the culmination of the spawning season often not the least reaction towards ship and gear can be observed and the trawl simply cuts out a portion according to the opening size. Even by the early types of midwater trawls, which failed in most other circumstances, spawning herring was caught quite regularly.

(c) Migrating schools (black sharp edged blots or vertical beams in midwater). In a most significant way these schools are formed by the Atlanto-Scandian herring during their migration to the spawning area. Actually these schools are egg-shaped, the longer axis in the horizontal line. They keep their shape day and night and travel continuously with a speed of about 40m/day in the direction they are bound for. In this state they are quite inaccessible for the midwater gear of the present type. Already in front of the approaching ship the schools often take flight as a whole and cannot be overtaken by the towing vessel. Those schools passed over by the ship always disappear to the sides or into the depth, before they can be reached by the net.

Comparable schools of North Sea herring and New England herring can be caught successfully, provided their attempts at escape between ship and trawl are watched by means of a backward directed sonar, and vessel and gear are manoeuvred adequately.

(d) Small groups and scattered schools (black sprinklings). Especially recovering spents are often split up into small groups which, calculated by target strength and catches, range from a few dozens to some hundred specimens. These sprinklings are usually arranged in a sort of layer near to the bottom with sometimes larger blots in between.

In small groups the fish have always a good chance to avoid the trawl, because the group reacts as a whole and the fish do not hamper each other. Usually, all small sprinklings indicated by the ship's sounder have disappeared before the net reaches them and only from the larger aggregations is some part caught.

Small schools of this type temporarily occur in connection with the diurnal vertical migration, and they may develop from homogenous layers in the disturbance area of the trawl.

Influence of diurnal migrations on capture

Before midwater trawls were employed the diurnal migrations of herring made it necessary to use different

types of gear during day (bottom trawl) and night (gillnet, purse seine). Theoretically, the midwater trawl can reach them in each depth. Actually fishing is too risky near rough bottom and during the night it is often hampered by drifters and purse seiners. These circumstances are usually not mentioned in the catch records of commercial trawlers, and comparisons of day and night catches are not necessarily an indication for the behaviour of fish.

When the types of aggregations do not change, but only their depth, no significant difference is observed in the amount of day and night catches. The hibernating herring layers could be midwater trawled successfully around the clock (with certain restrictions only during the short time of up or down movements). On the other hand the migrating schools of Atlanto-Scandian herring were always on their guard and were difficult to outwit both at day and at night.

Marked differences in the catching efficiency due to the fish behaviour occur when the type of aggregation changes in course of diurnal migration. The North Sea aggregations of pre-spawners are in daytime paying targets for midwater trawling, but in dusk they split up often into small schools which rise to the surface. In this phase they are rarely accessible to the gear. Widely scattered layers during night at the surface usually result in relatively low catches per unit time.

On the Georges Bank and off the New England coast conditions for the capture of pre-spawners were somewhat different in recent years. This is due to the bottom conditions and the large masses of fish. In daytime herring stayed preferably between steep rocks, where they were safe from any gear In the evening large and dense schools rose to the surface. Although these schools reacted strongly to the gear, nevertheless good catches were possible because of density and size. Near the surface these schools dispersed into "clouds" which frequently fused to large concentrations Under these conditions incredibly good catches were made, i.e. up to 70 T per haul or 200 T per night, with a 3,000 hp vessel and a 1,600 mesh circumference midwater trawl.

As already mentioned, the permanent layers of Atlanto-Scandian pre-spawners off the Norwegian coast mostly avoided the gear, but in a few cases their watchfulness ceased for some hours between midnight and dawn. They then passed through the net opening, even close to the frame ropes. It seems likely that this short-time opportunity for capture is due to "sleeping" as was observed by a Sowjet research submarine in the NE Atlantic (Radakov and Solowjew, 1959).

Reactions to ship and gear

More detailed observations of the fish reactions could be made after the combination of sonar (and occasionally "panorama" sonar), ship's sounder and "multi-netsonde" was employed on research vessels. The gear used during these cruises was mostly a four-seam net of 1,600 meshes (stretched mesh = 20 cm) in circumference. The theoretical net opening area (opening height x-width) of this trawl, which is still a standard gear of the German 2,000 to 3,000 hp trawlers, is about 20×30 m.

Reactions to the ship were regularly observed in Atlanto-Scandian herring at the end of the hibernating phase when the aggregations were in a transitional state between layer and school. These aggregations stayed motionless until the vessel had approached to about 150 m. Then they took flight and kept this distance for 30 to 50 sec, until the ship drew up. In the following migrating phase the schools of this herring were often too alert and their swimming power was so strong that they could not be overtaken by the towing vessel (> 3.5 kn), much less reached by the net. Those eventually picked by the ship's sounder and then by the netsonde had meanwhile often dived for 50 to 100 m.

Schools of other stocks passed over by the towing vessel usually dive between ship and gear for about 20 m, which may be due partly to the ship's noises, partly to the warps, from which they keep a distance of some metres. A more significant effect is caused by the otter boards and bridles which split larger schools into parts. When the net reaches them, those groups usually have a distance of more than 10 m aside and below the gear. Above the trawl herring is rarely observed. The preferred flight direction is downward.

The fish herded between the warps enter the net in the centre of the opening, keeping the already mentioned distance of about 6 m from the frame lines. Frequently they try to keep up with the towing speed for some time or to escape downward; then the net has to be lowered at the right moment.

In the forward directed transducer of the "multi-netsonde" it could sometimes be observed that real schools reacted in a distance of 20 and even 40 m to the approaching trawl. The Atlanto-Scandian herring then increased the speed and escaped into the depth. Others keep up with the gear for 20 to 30 sec and then are overtaken. In large schools a complete confusion may develop under such conditions and the obviously exhausted fish then fill the whole opening of the net.

A flight reaction directed upward was observed regularly in the nocturnal layers of the Goerges Bank and occasionally in the Skagerrak. Here the net had to be towed very close to the surface otherwise the fish escaped above the headline.

When already within the front part of the net, 10 or 20 m behind the headline, herring still try to keep distance from the panels, which is indicated by transducers fixed there. However, where the net narrows towards the funnel usually many gilled fishes show that they finally tried to escape through the meshes.

CONCLUSIONS

In most of the free field observations it cannot be quite clearly decided by which stimuli the reactions are caused. The responses of herring to the ship are obviously due to propeller noises for which indications will be given in connection with learning. In tank experiments reactions to moved gear (or gear substitutes) depended on a certain light supply (Blaxter and Parrish, 1966), but in sea generally no difference in reactions between day and night could be observed, and the presence of luminous organisms in the water was in most cases unlikely. Besides, the distances of reaction (up to 40 m) were often too large for visual perception. It seems more probable

that turbulences, pressure phenomena and noises caused by the towed gear were responsible for the reactions.

The outstanding ability of escape in the schools of adult Atlanto-Scandian herring is certainly to a good deal due to their alertness, but is supported very much by the large size of the individuals. The swimming speed of herring is in the order of seven body lengths per second (Blaxter, 1967), which they obviously can stand for a considerable time. That means at a towing speed of 3.5 kn (180 cm/sec), a medium sized herring of 26 cm in length can just keep up for a while, but an oceanic herring of 34 cm can get away with a speed of about 240 cm/sec (about 5 kn).

Whether learning has an effect on fish behaviour in connection with trawling is still an open question. Devold (1967) has pointed out that the Atlanto-Scandian herring has changed behaviour considerably since they have been fished intensely. Margetts (1967) observed that schools of Shetland herring took little or no notice of a ship running free and fast, but avoided a slow moving one and especially a labouring one towing a trawl. From this the conclusion could be drawn that the fish had learned to distinguish between harmless and dangerous noises.

In Icelandic purse seining, herring make a difference between ships of different propeller noises which would, however, be equally dangerous (Hjul and Brady, 1967). This suggests that a stronger reaction to distinct noise characteristics (especially low frequencies) is innate. On the American coast the unusually good herring catches in recent years are obviously not due to less experienced fish, as sometimes suggested, but rather to the large and dense fish aggregations.

Conclusions drawn from the reactions towards the gear have already led to important amendments of the earlier net types, a development which has certainly not yet come to an end. One of the first demands was that the trawls should be as large as possible because of the tendency of the herring to keep a certain distance from the frame lines of the net opening. In consequence, the netmouth area was increased from about 250 m^2 in the early sixties to about 2,100 m^2 recently (detailed description in Schärfe, 1969). An improvement derived from the observation that herring keep this distance even in the whole front part of the net was, to enlarge the mesh size in order to reduce the towing resistance and stow to save net material. Nets which would require 2,200 or even 2,700 meshes in circumference of the former ordinary size (20 cm stretched) now have only 788 and 948 meshes respectively, but with a mesh size of 56 cm stretched. Nets of this type have been employed successfully also for catching scattered redfish and cod.

Because of the high swimming speed of certain herring schools the towing power of the trawlers was increased to cope with the larger trawls. Whereas the distant water trawlers built in the years before 1960 usually had less than 2,000 hp, the engine output increased gradually to about 2,500 hp in 1965 to 3,000 hp in 1967 and trawlers presently planned will reach even 4,000 hp.

The performance of the acoustic devices is in a corresponding development with the demands of mid-water trawling Multi-netsondes of different types are now produced for commercial fisheries.

Consideration are being made for computerized evaluation of data available on fish behaviour (Falkenthal and Hering, 1969).

In fisheries, as in most other industries, there is a trend towards computerized automation of control and coordination of partial processes. Whether and to what extent a complex subject like fish behaviour can be included in such a system, e.g. for commercial trawling, will have to be seen in future.

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DISCUSSION

MATERIALS, DESIGN, CONSTRUCTION AND SELECTION OF GEAR

v. Brandt (Germany) Chairman: As the term "Aimed Trawling" has different meanings, a more precise definition is desirable, so perhaps Dr. Schärfe, who created this term, would give his definition.

Schärfe (FAO): The term is a verbal translation of "Gezielte Schleppnetzfischerei" and was meant to signify the rational attempt to efficiently hit a located fish school with the trawl, particularly in midwater trawling where this problem is of crucial importance. At an early stage of development the "aiming" concept was also extended to bottom trawling which led to more emphasis on the consideration of environmental aspects such as water depth, bottom configuration and nature of bottom.

The extended application of midwater trawling to more difficult fishing conditions increased the requirements regarding the efficiency of the "aiming" concept with respect to fish movements and its reactions towards the trawl as well as other environmental factors such as wind and current or rather their influence on the track of the vessel and the gear. Also the rational selection of gear and rig and its efficient operation or exchange for optimum adaptation to varying conditions could be considered as rationally aimed action. I would therefore like to suggest the following definition of the term "aimed trawling" according to the present state of development as I see it:

"Rationally directed instrument controlled trawl hunting with continuous on time reference (and respective updating) to fish and environment, including essential operational aspects such as gear selection and its adaptation to fishing conditions, gear performance in action, and control of the catching process."

v. Brandt (Germany) Chairman: The emphasis on instrumented control of the catching process is exactly in line with the expected future development of fish catching techniques and also the prerequisite for the automation of fishing methods. Another point I would like to mention is the difficulty in distinguishing between bottom trawl, semi-pelagic trawl and midwater trawl. Most definitions so far are based on the action pattern of the gear, that is, the bottom trawl is in continuous contact—at least the groundrope—with the bottom, and it does not matter whether it has a flat or a high opening. The semi-pelagic trawl has the otter boards on the bottom but the net, including the footrope, travels some distance off the bottom. With the midwater trawl the whole gear, including the otter boards, operates in free water. There are also combination trawls which can be operated on, close to or at any distance from the bottom. In French literature, trawl gears are defined, not according to the behaviour of the gear, but to the vertical distribution of the fish. Consequently a semi-pelagic trawl in the French definition means that semi-pelagic fish near the bottom are to be caught and this would include also high-opening bottom trawls. I think this non-uniformity can be accepted and it is not necessary to decide here which definition is preferable, but the matter must be kept in mind for the following discussions.

McNeely (USA) Rapporteur: As pointed out by **v. Brandt**, successful midwater trawling was first achieved in 1949 in the form of pair trawling. About this time both private and governmental researchers in many parts of the world intensified their efforts to develop a successful one-boat midwater trawl. The 1957 FAO International Fishing Gear Congress contained several reports on the state of development and during the 1963 Second FAO World Fishing Gear Congress considerable discussion ensued concerning midwater trawling and related subjects such as depth telemetry equipment, identification of echograms, behaviour of fish, a variety of net designs, otter boards and other shearing devices and flotation. Great progress has been made since then and successful one-boat midwater trawling is now an accepted practice. The two Congresses undoubtedly contributed significantly to the present state of the art. We can no longer tolerate having only good, easily recognizable echosoundings and sonar recordings of fish, a trawl and related accessories with proven catching ability, and a system to allow placement of the trawl at the depth of the located school. We must also be capable of "aiming" the trawl once the gear is shot in order to precisely intercept the school of fish.

Early experimenters, after completing a tow and finding no fish in the net, would ponder the following: (1) is my design of net capable of capturing fish? (2) was the echo trace in fact fish? (3) was my trawl positioned at the correct depth? (4) was I towing fast enough? (5) did the vessel noise scare the fish? (6) did they swim out of the net during retrieval? The fact that these questions have rarely been asked in recent years illustrates some of the milestones that have been passed in development of one-boat midwater trawling.

v. Brandt's paper provides background information on the history of development of one-boat midwater trawling, citing both the advantages and disadvantages over the two-boat system which was its predecessor. For the co-ordination of trawl depth with the frequent changes in depth of fish during a tow, depth telemeters are considered inferior to the echo sounding netsonde. Very large nets requiring greater than normal towing power were a contributory factor in the successful development of the one-boat system. A table in this paper compares the relative characteristics of one-boat midwater trawls used throughout the world. The close cousins of midwater trawls such as high-opening bottom trawls, semi-pelagic trawls and multipurpose or "Universal" trawls used both in midwater and on the bottom are also discussed and finally prospects for the possible further evolution of trawl systems are considered.

With information on characteristics of twines, ropes and netting described and tabulated in the contributions by **v. Brandt** and **Klust, Honda** and the **Japanese Chemical Fibers Association** factors are identified which can have a decided influence on trawl design and selection. **Portier** points out that high-opening semi-pelagic trawls must be towed at a speed of 4 knots in order to catch mackerel and this necessitates a reduction in size of gear normally used to take spawning herring. However, if smaller diameter twine was used and was supported by multiple riblines to take up the heavy strain, size reduction might not have to be so severe.

It is reported that polyethylene is replacing polyamide for trawl construction in Japan. The data presented in the same contribution by the **Japanese Chemical Fibers Association** on the relative abrasion resistance is most welcome, but it could be improved on by tests conducted not just in the laboratory for short periods or time on new materials and later when the materials have been used and are ready for discard, but by simulation of actual usage in fisheries with due consideration of time, temperature, depth and pressure.

In most midwater trawling operations, changes in towing power are commonly used to adjust the depth of the net and a direct result of this tactic is a change in the geometrical configuration of the gear due to increased or decreased strain on the netting. Elongation of netting and other material used in the net's construction is certainly a factor to be considered in this instance.

Whenever riblines are used to take up load, the great strength of polyamide is needed, but the lower elasticity of polyester is sometimes desirable to help retain proper net configuration.

The only solution seems to be a combination of the two fibres into a single rope. Some manufacturers are doing this now. Due to the ever changing loads imposed on ropes during fishing operations, elastic recovery of synthetic fibres is of vital importance in ropes used in trawl nets. (See **Honda, v. Brandt** and **Klust**.) This point is well taken, as a mis-shaped net will certainly not have optimum catching efficiency. Since **Honda's** comparative tests were concerned with elongation and elastic recovery of new ropes and only the breaking strength of used rope, it might be useful to conduct tests to compare elongation and elastic recovery over the entire life span of the ropes to see if the initial relative characteristics remain constant.

In the USA, experiments with polyamide monofilament netting in midwater trawls have been in progress since 1962. In that period empirical data have been collected on relative catch rates of pelagic trawls built to identical specifications with the exception of normal twine or small diameter monofilament netting respectively. In every instance where a comparison could be attempted, the monofilament net caught more fish than the conventional net. However, this may not have been caused by an inability of the fish to see the net and escape, but more likely the added efficiency was due to the small diameter of the filament as it was also noted that catch rates increased whenever smaller size multifilament twines were used. Another indication that fish were able to discern the presence of monofilament netting is that gilling of fish was negligible in both the forward and intermediate sections of both types of nets (**McNeely**).

According to a Japanese net manufacturer, monofilament is coming into use in midwater trawls and American king-crab vessels in Alaska report seeing monofilament trawls taking excellent catches of pollock in the Bering Sea. However, of the many Japanese papers presented at this Conference, only one (**Miyazaki** *et al.*) refers to use of monofilament and in this case only in certain sections of small otter trawls. Comment from Japanese delegates or others who may have additional information on the use of monofilament in midwater and bottom trawls is invited.

In the technological development of "aimed" trawling, the starting point had to be knowledge of the characteristics and environment of the animals sought. In most instances these characteristics and conditions change frequently and sometimes with predictable regularity. **Portier** stresses the necessity to match the gear to the species and its environment. This view is supported by **Dickson** as well as by **Maucorps** and **Portier**, all emphasizing the need for the consideration of fish behaviour. **Mohr** describes, as an example, the radical changes in behaviour of different stocks of herring that occur during different times of the year.

For maximum efficiency in any trawling operation, it is vital that gear, vessel, behaviour and size of the fish, sea conditions, severity of weather, bottom types encountered, and many other parameters must be seriously considered before a rational selection of gear can be made. **Dickson** has compiled a checklist which can be of considerable value to both marine scientists and commercial fishermen for gear selection. He points out the need to take into consideration local knowledge of available species of fish and conditions at sea, the size of vessels, and towing power available. Rather than developing a radically new design he suggests starting with existing gear and only after much thought and consideration of his list of variables should even slight modification be made to proven gear.

Nakamura presents some interesting results of tank experiments with trawl models and vividly illustrates methods of achieving vertical opening by using a six-seam net or by vertically stacking one net on top of another, or a large horizontal opening by arranging two nets side by side. He also describes what he has termed the "hop trawl" technique, that is, to lower the net on the bottom only for the time when fish are present and how, by slowing down the vessel, greater vertical opening can be achieved when semi-pelagic fish are encountered.

Koyama developed a methematical method of matching the vessel to trawl gear. On the base of considerable empirical data over a wide range of vessel horse power tables were assembled to show the relation between length of headline and available towing power. He stresses the need to match winch power to vessel horse power to gain maximum efficiency. A graph showing the change of coefficient of drag of trawl warps with change in angle of attack can be questioned because it is assumed that trawl warps operate in a straight line rather than in a catenary configuration.

Freedman suggests that by optimum matching of the trawl gear to the vessel a gain of 30 to 50 per cent in efficiency can be achieved. Due consideration is given to the optimum trawling speed for a particular species of fish and to the selection of the correct gear to attain that end. Since the difficulties of obtaining valid information through model tests—such as **Reynold's** criteria and **Froude's** generalized criteria—can be overcome through simplification and the choice of proper scale model tests are considered valuable as a first step but should be complemented by sea tests of full scale gear to check the calculated design parameters.

v. Brandt (Germany) Chairman: It appears there is no uniformity in the views expressed by various contributors with regard to the best twine material for trawl nets. This is not surprising because the choice depends on quite a number of not only technical but also economical factors, the relative importance of which may vary from country to country and from fishery to fishery. The actual selection is therefore usually a compromise which must not necessarily represent the optimum technical solution.

I would like to mention in connection with net materials and netting that there exists an international organization for standardization, the ISO in London, with a special subcommittee for netting materials and a working group for testing. The idea for this sub-committee evolved from the first FAO International Fishing Gear Congress in 1957. Its main task is to standardize technical terms and to propose standard testing techniques. These are given as recommendations to the member countries of ISO. Most of the countries of the world are members or observers. I think more than this should be done and I would like to repeat a proposal made by the Dutch delegation during the First FAO Fishing Gear Congress, that is, to assemble an extended multilingual catalogue of all terms relating to trawling and trawls. I am sure if this meeting would make such a request to the ISO there would be a favourable reaction.

Margetts (UK): Endorsed the Chairman's remarks on the need for international standardization of technical terms and of testing methods in the field of gear technology. The ISO sub-committee dealing with this would be more efficient if more countries, expecially non-European countries, took an active part in its work.

Alverson (USA): The Chairman's proposal on further international work on standardization of technical terms concerning material used for fishing nets or to describe their construction features is endorsed.

De Rango (France): I have no objections against the Chairman's proposal on standardization, but I want to draw your attention to the fact that the OECD is presently working on a multilingual dictionary. Co-ordination is therefore needed to avoid duplication.

V. Paz-Andrade (Spain): I think one should not only aim at a standardization of terms but also try to achieve a more strict technical language. I would therefore suggest that representatives in various countries request their official language academies to review the terms used in the fishing industry.

Alverson (USA): I don't think the immediate need is for dictionary definition but rather for a standardization of the terms so as to facilitate communications at conferences of this type and when corresponding between workers of different countries.

Nomura (Japan): The use of combination twine netting in Japan is almost completely restricted to purse seines and the most common combinations are polyamide with polyvinyliden chloride and polyamide with polyvinyl alcohol. The aim of combination twines is to combine, in one material, the favourable characteristics of several materials such as high breaking strength, specific gravity, price and availability for a specific purpose. Trawls in Japan are almost exclusively made of single material twines.

Kristjonsson (FAO): As far as I know in Japan large and medium size trawls are almost exclusively made of polyethylene. Knotless twisted netting is quite common for medium distance trawlers, particularly for the upper panels and often for the entire net. Because of difficulties in repairing knotless nets, bellies and codends are often made of knotted netting which is also preferred for the trawls of long distance trawlers which operate for long periods far from net mending facilities on shore.

Ben-Yami (Israel): The upper parts of the bottom trawl nets in Israel are of polyethylene which is lighter than water. The lower parts are made of either staple nylon or Kuralon, both heavier than water. The difficulties due to the different stretch ratios were solved by trial and error, and now we know how to hang these nets. The lighter-than-water top causes the trawl net to open under static conditions. When a forward motion is applied to the trawl, the hydrodynamic forces take over and keep the net open. Thus, few floats are needed and some fishermen do not use floats at all. To what extent is polypropylene now used for trawl nets and is there any progress in its qualities, such as improved resistance to light and abrasion?

Margetts (UK): Polypropylene is commonly used for bottom trawls in the UK where it is keenly competitive with other synthetic fibres, especially polyethylene. It is used in both multifilament and split film forms.

Keirat (Germany): Polypropylene is not used for trawlnets in Germany.

Radhakrishnan (India): In many developing countries in the tropics fishing is carried out near the coast in depths down to 25 fathoms, mainly with small sized vessels of about 30–35 feet and only by a few larger trawlers. For these small vessels with low-powered engines the use of light nets is a very big advantage. I should like to know if there have been experiments to compare the effectiveness of monofilament nets with nets of a conventional construction.

Barros Feu (Portugal): Would monofilament nylon be advantageous over multifilament for midwater trawling with a small trawler of about 200 tons and 600 hp at about 3 knots?

Alverson (USA): Midwater trawling can also be successful with low powered vessels. However, success for such an operation is highly dependent on the behaviour of the fish. Slow-swimming sluggish species, such as Pacific hake, have been taken by low powered vessels operating at relatively low speed. Our experience with monofilament netting demonstrates some handling and repair problems but these disadvantages were offset by increased catches.

Nomura (Japan): I do not have much personal experience with monofilament in trawlnets, but I understand that **Miyazaki's** experiments on small boats indicate that the most important factor in favour of monofilament is its much lower visibility as compared with multifilament. This was found to be more important for fast-swimming round fish as there was little difference in the catches of flatfish. These experiments were conducted during daytime.

Kristjonsson (FAO): According to personal communications from **Miyazaki**, about 1 per cent of small (40–80 hp) Japanese inshore trawlers use monofilament trawls. These nets are not made completely of monofilament, but the square, the aft part of the wings and the funnel consist of this "invisible material", while the rest is made of multifilament twine. The theory of capture is that fish are guided by the visible front wings into the less visible net body made of monofilament. These nets are particularly effective in clear, shallow water in daytime.

Japan exports quantitites of monofilament netting for trawls, e.g. to Cuba. Mechanical netting looms can now cope with up to 0.9 mm diameter filaments but new looms are being developed to braid monofilaments up to 1.5 mm diameter which will make it possible to use this material in nets for trawlers of greater horsepower than the approximate 200 hp which is the present limit.

Schärfe (FAO): Netting in trawls need not necessarily be invisible. It is supposed to have a guiding effect, which with invisible monofilament would not be achieved. Consequently fish would be more likely to go through the invisible net and escape or get gilled, so that smaller meshes would have to be used which would probably counteract the saving in towing resistance which is expected from monofilament netting.

McNeely (USA) Rapporteur: In our comparative trawling trials with monofilament and multifilament trawls the mesh size was equal, and as no difference in gilling the fish in the front parts of the trawls was experienced, factors other than visibility, such as perception of vibration or pressure waves, may be involved.

Schärfe (FAO): If fish are able to "feel" monofilament netting, then transparency would no longer matter, and no difference from multifilament netting could be expected.

It appears that the monofilament used in **McNeely's** comparative trials was thinner than the multifilament twine used in the standard trawl. As monofilament is weaker and has less breaking strength when knotted, the monofilament trawl must have been considerably weaker.

McNeely (USA) Rapporteur: It is true that the monofilament net was weaker and often broke. This was overcome by using a considerable number of riblines to take loads throughout the net, but without these the net would have disintegrated in a very short time. This type of net has been used by commercial vessels and admittedly it took considerably more repair than conventional trawls made of twisted knotted netting.

Mohr (Germany): There are still many gaps in our knowledge of the herring's responses towards pelagic trawls. The most serious lack is that we do not know which sort of stimuli causes reactions which occur in the same manner during daytime and in darkness. In tank experiments with gear

substitutes herring respond almost exclusively to visual stimuli. It is possible that low frequency sounds caused by the gear are responsible to some extent for reactions during darkness.

Parrish (UK): I endorse **Mohr's** remarks that it is important to bear in mind, in studying the behaviour of species, that they may change their reaction to gears at different times and places. The problem is to to find the key stimulating factor or combination of factors which activates the fish. In the research programme at my own laboratory investigations are being made of both acoustic and visual stimuli. The results of our tank experiments have pointed to the dominant importance of visual stimuli in governing the reactions of fish to towed gears. One of the difficulties is to explain why some gears are as effective in day as in night fishing. It is possible that bioluminescence generated by the action of the gear plays an important role. Experiments with towed manned underwater vehicles are now being planned to provide direct information on the importance of this and other factors and parallel work is being conducted on the sensitivity and reactivity of fish to acoustic stimuli.

Klima (USA): Results from experiments with only one type of stimuli on fish reactions may be misleading as in fact the phenomena that activate fish are combinations of different kinds of stimuli. Further the rate of change of the stimulus is important in controlling the animals fright reaction.

Blaxter (UK): There is a contradiction between the results of visual stimuli tests in tanks and at sea. It is difficult to simulate low frequency sound and pressure waves and other phenomena in a test tank. I share **Klima's** view on the combined effect of stimuli on fish reactions. I believe that future tests on fish behaviour in relation to gear should be carried out at sea, using for instance the sector scanner.

Okonski (FAO, Argentina): Investigations on the anchovetta stocks of the Argentinian coast showed that the behaviour of this fish changed considerably during the season with respect to the same fishing gear (trawls or purse seines).

Kjell Olsen (Norway): Experiments have been conducted in Norway with low frequency noises and their effects on the behaviour of herring. These experiments were undertaken in an open fjord. We found that it might well be that herring reacts to such stimuli created by trawls both during daytime and night time. If there were measured data available on the acoustic stimuli or the pressure waves which travel in front of the trawls these could be compared with the known audible threshhold values in fish and some interesting conclusions might be possible.

Ben Yami (Israel): I seem to remember that different plankton nets were tank-tested and flow velocities in the mouth area were measured. I wonder whether these results could be applied to trawls.

Alverson (USA): I know of one particular experiment of this type conducted in the USA which was published by **Barclay.** This related to the behaviour of organisms in front of the plankton net in terms of pressure waves, but the analysis was almost strictly based on a mathematical hypothesis rather than on empirical observation.

v. Brandt (Germany) Chairman: An important feature with regard to fish reactions is the mesh size in the front part of trawls the function of which is guidance.

Blaxter (UK): I noted from **Mohr's** paper that a mesh size of 56 cm stretched has been used in the front part of trawls with no noticeable decrease in the catch. In tank experiments we have used 120 cm meshes when herding fish and I believe that if one wants to herd the fish one could possibly increase the mesh size further.

Engel (Germany): The mesh size of 56 cm stretched was the largest that could be machine braided at that time. No longer are there technical problems in machine braiding larger mesh sizes and they are already being used for trawls. There is, however, some problem regarding the handling of such netting on board as it tends to get entangled with the floats.

Schärfe (FAO): There are several ways of overcoming entangling problems. One way would be to arrange the spherical floats in strings covered with small meshed netting. Another way would be to use buoyant net materials in the upper panel of the trawl, as mentioned by **Ben Yami** earlier. A third way would be to reduce or avoid entanglement of large meshes by using a net drum, and it would appear advisable that other fisheries learn from American experience in this respect.

Larsson (Sweden): Trawlers are now being built and planned with engines up to 3 to 4,000 hp to tow super trawls. In my view it seems important to find some other solution to the problem of one-boat midwater trawling for trawlers with 400 to 1,500 hp which are common, for instance, in Sweden. Having acted as a naval architect and ships' surveyor for more than 45 years I have had good opportunities to learn how important it is to reduce resistance of every kind in order to promote speed. The same applies to a trawl gear, even if you only want to reduce the cost of fuel. I still believe that a good speed will be of great importance in increasing the catching ability of a trawl, but the net should be so arranged as to avoid frightening fish away from the front of the trawlmouth.

With the aid of instruments we now know that the normal way for fish to escape a trawl in motion is either downwards or upwards. Also, fish entering the trawl are normally found at a certain distance from the netting. From this I conclude that: the net mouth should have considerable height, it is unnecessary to have continuous netting in the mouth of the trawl and everything possible should be done to decrease the pressure in front of the trawl mouth.

The big meshes now used for the foremost parts of trawls represent some progress. I made such a recommendation in London in 1963. My new Phantom Trawl model 1970 is based on the following considerations: an ordinary four panel pelagic trawl with an opening height of say 20 m can be towed by a certain trawler at say 3 knots. This is not a super trawl but certainly it is not a very small net either. I recommend having instead a similar net with an opening height of 14 m. This has half the resistance and the trawling speed will increase to about 3.7 knots, provided the same size of meshes and twines are used and floats and weights are in accordance with the smaller size of the trawl. I further propose leaving all floats, chains and weights ashore and arranging for extra pieces of small meshed netting in such a way that there will be a good opening (about 1 m) between the aft edges of these net pieces and the trawlnet on the half length of headline and footrope—and tapering towards the wings. These extra net pieces shall have a small angle of attack (5 to 10°) from aft to forward. Finally, a suitable number of trawl paravanes should be placed at the fore edges of the extra nets, either directly or fixed to lines athwartships which run above or respectively below and in advance of the extra nets and are connected to same by short lines. The extra net pieces serve two purposes: first they will cause a lifting or respectively depressing force to the fore parts of the ordinary net; secondly, they will make it simpler to handle the paravanes which, by the way, is a question of seamanship. I am ready to instruct anyone who wants to know how.

At the Second FAO World Fishing Gear Congress, 1963, I introduced the term "hover trawl". By that I mean a trawl, the ordinary netting of which never comes into direct contact with the seabed. This term applies also to my new proposal. It is worth mentioning that a hover-trawl will never break an underwater cable on the seabed.

Portier (France): There are many aspects of trawl design, but it is accepted that the net shape, the nature and thickness of the material used as well as the towing speed, influence efficiency. In addition to this the bottom nature and fishery conditions, together with changes in the behaviour of the species sought should also be considered.

Thus several types of semi-pelagic or high-opening bottom trawls, are used which differ mainly in the arrangement of their rigging and the related passing of the net into close contact with or at a distance of 1 or 2 metres from the bottom.

For instance, during herring fishing on spawning grounds, fishermen are using large trawls which are not permanently towed, but are set towards fish located by means of sonar and sounder. Twines in the fore part of the net are relatively thin, but only those in the aft part are reinforced to withstand the heavy catches. Smaller and stronger trawls are preferred for fishing cod, whiting and coalfish, in relation to the longer duration of the tow and their closer contact with the bottom. Finally, smaller trawls of elongated shape and made of thin twines are used for inshore mackerel trawling which requires a high towing speed (in excess of 4 knots). In each case it is possible to relate the net dimension and the towing speed to the trawler horsepower.

To conclude, the terms "semi-pelagic" and "high-opening bottom trawl" apply to a great variety of nets which have an important opening height as a common characteristic and which are suited not only to the vessel horsepower, but also to the different species sought.

Di Mento (Italy): Beginning with observation of the behaviour of the "Aguglia" (gar-fish, *Belone belone*) and, of course, considering the particular fishing conditions in the Adriatic Sea, we have developed a two-boat trawl, that works with the headline and part of the square above the surface. This trawl which catches only Belone has no floats at all, it being the action of the water that opens the net. Last summer a few pairs of trawlers, some of 400 hp, were able to fish from May until September with good results.

Besancon (Netherlands): In Table I of **v. Brandt's** review paper I miss the mean towing speed. In the Dutch fisheries we are following the trends set by **Schärfe** for pelagic trawling, with one exception. The "stalking the prey" or "outwitting" method which he advocates is not being followed. Dutch skippers stick to the "chasing" method. We do not use nets of 1400, 1600 and 2000 meshes circumference (on the base of 200 mm stretched mesh) with 560 mm meshes in the front part. Contrary to the 5 to 8 m² Süberkrüb otter boards used by West German trawlers, in Holland 4.6 m² Süberkrüb boards are used. The difference in size could be due to different tactics (different speeds). In my opinion the mean towing speed should be included to give a clear picture of the relation between size of net and otter boards versus speed.

Dickson (FAO, Poland): It has always seemed to me that the determination of optimum towing speed by trawling was particularly difficult, because of the many factors that are compounded. If you work at constant warp length then at low speeds the boards fall inwards and at high speeds the gear leaves the bottom and before then the ground reaction is reduced below its optimum. The gear thus becomes ineffective at both low and high speeds, but this is not related to optimum towing speed as far as fish behaviour is concerned. If the correct warp length is chosen for each speed, headline height falls at increasing speed and spread may increase. Thus catch rates depends upon a compound of changing speed and changing net dimensions which, even if they are measured, can give different answers in different vertical fish distributions which may or may not be accurately known. Determination of optimum towing speed with one net may or may not give a good lead to optimum towing speed with another net.

Doust (Canada): Early experiments in the UK on the behaviour of trawl gear were made at the Ships Division, NPL, which showed the important effect of vessel motion on warp tensions. With a full catch and increased net resistance, the oscillating motion of the stern played an important role. In this situation it is even more necessary to provide the least possible motion of the vessel at the after end.

Hamlin (USA): In 1968 my company (Ocean Research Corporation) carried out for the Bureau of Commercial Fisheries a vessel design study for the New England trawl fishery on Georges Bank. The purpose of this study was:

1. To design a mathematical model of the fishery;
2. to use this model to derive an optimum vessel for the fishery.

We relied heavily on **Koyama's** work, most of which is reported in his present paper and on work by **Dickson, Crewe** and **Carrothers.** We are now completing the same type of study relative to the New England shrimp trawling industry. This is a relatively new industry, based on *Pandalus borealis*, of which nearly 30,000,000 lb were landed in 1969. This type of study is made possible by the high speed of calculation of the computer. For instance, the Georges Bank study involved calculating the characteristics of 480 vessel/net systems, testing them according to return on investment, and printing out the characteristics of 60 selected vessels. This took eight minutes at a cost of about $100, but the computer must be treated with caution.

In the Georges Bank model the scheme starts with the primary catching element, the net/engine system, and ends with the calculation of return on investment, which was stipulated as the criterion of optimality for the study.

In the shrimp study, a different approach was used in programming the computer. Here the entire system is broken down into sub-systems, each dealing with an individual aspect of the operation, e.g. fishing gear. This sub-system output is introduced into the main system program which produces a vessel description for each set of variables. Although there is certainly need for perfection, these techniques are already useful to the industry, for instance to show that more water is strained through a large net towed slowly than a small net towed rapidly, and much more can be done in the future.

For making best use of the tools of mathematical modelling and computer processing I would like to suggest that FAO creates a working party to coordinate use of these tools, with respect to nomenclature, measurement, specifications and requirements, general procedures, and areas of greatest need. Several delegates have worked or are working with these tools, and it would seem of advantage to agree on the items noted above.

Schärfe (FAO): When making up mathematical models of fisheries there is a danger of too far-going simplification which may badly affect the results. The present model seems for instance to assume that fish behaviour is constant which is not the case. The fact that with a given towing power more water is strained with large gear at low speed than with small gear at high speed has been well known since the early days of hydrodynamics and probably programmed. It may therefore

not be a convincing proof of the correctness of the scheme as a whole.

Alverson (USA): I should like to repeat **Schärfe's** caution in placing too great a reliance on computer analysis for optimizing vessel size for a particular fishery. Not only is the catching coefficient not in linear relationship for trawls towed at different speeds but it should be noted that many vessels earn their income from a number of fisheries depending on seasonal availability and demand. In this sense the multiple purpose design features of the vessel are of great importance. As vessel designers can rarely forecast changing demand and changes in the availability of resources it would perhaps be better to forecast the optimum characteristics of gears for any fishery in which the vessel might become involved.

Regardless of the underlying problem confronting evaluation of outputs obtained from such system studies I do support the recommendation of **Hamlin** and hope that FAO will respond positively to his suggestion.

Gurtner (FAO): Informed that FAO was working on somewhat similar lines and felt that **Hamlin's** suggestion to convene a working group was a very valuable one. He was not certain to what extent it would be possible to implement this, but FAO would certainly keep the suggestion in mind.

Hamlin (USA): With reference to the criticism of our approach that it does not deal with actual boats already built, the output data for a fishery can be plotted in a variety of ways as desired. From these plots can be determined either (1) the most desirable fishing gear and tactics for an existing boat, or (2) what changes should be made to improve its performance. The peaks of the curves of optimality for vessels seem to be rather flat, so it may be that gear selection and fishing tactics are of greater importance than vessel characteristics.

When the shrimp boats were studied it was kept in mind that these boats for some months go lobster fishing and the results month by month were considered so that later it could be decided month by month which would be the most profitable fishery.

v. Brandt (Germany) Chairman: One relevant question which I should like comments on is whether there are occasions when midwater trawling is superior to purse seining.

Mohr (Germany): I have no personal experience in purse seining, but could offer an example. When midwater trawling for blue whiting in winter we had good success with extended but thin layers of fish in depths of 100–300 metres. As the fish did not react to the net we could fairly accurately calculate the fish density by the volume of water strained by the net in a certain period of time. This was found to be only 25–30 fishes per 1000 m^3 water. This density is certainly too low for purse seining, but with the midwater trawl 25 t per hour could easily be achieved.

Middtun (Norway): Fish often school during the day and disperse into layers during the night. This would indicate that boats should purse seine during the day and use midwater trawls during the night. Could vessels be constructed so that they could do this?

v. Brandt (Germany) Chairman: I think this is more a question of crew experience. Both purse seining and midwater trawling require considerable skill and it may be difficult to find crews adequately experienced in both fishing methods.

Traung (FAO): As this would be a continuous day and night operation I believe that such vessels have to have a two-watch system and then one part of the crew could be experienced in purse seining and the other in midwater trawling.

Steinar Olsen (FAO): One may not be able to find these fishermen today but is it not possible to train them?

Chenard (Canada): In Canada we are lately using the experience of our practical fishermen. They train in midwater trawling as well as in purse seining both in a school and at sea. We have at present under construction four combination vessels incorporating these two types of fishing, two of them now commissioned. They measure 155 ft loa by 30 ft in width and each one can carry 375 tons (short tons) of herring and 250 tons of groundfish. All vessels are equipped with refrigerated sea water systems capable of maintaining the catch of herring in good quality for five days and the main engine has a power of 1125 bhp at 1225 rpm.

Conversion from purse seining to midwater trawling can be done at sea within one hour. Purse seining is carried on in wind velocities not exceeding 25 mph, while midwater trawling can be carried on in wind velocities up to 45 mph. We are quite sure our crews will work efficiently with these two types of gear.

Doust (Canada): In collaboration with the New Brunswick Fisheries Department we have developed combination vessels suitable for purse seining and midwater trawling. The original version is intended to be used for training purposes but in addition it has a commercial capability. Furthermore, it can easily be converted back to a full commercial vessel, if desired.

Portier (France): There are many ways of understanding trawl designs, but it is accepted that net shape, nature and thickness of the material used and the towing speed, influence gear efficiency. In addition to this one should mention bottom nature and fishery conditions, together with changes in the behaviour of the species sought.

Thus several types of semi-pelagic trawls, or high-opening bottom trawls, are used, which differ mainly by the arrangement of their rigging and the related passing of the net into close contact with or at a distance of 1 or 2 metres from the bottom. For instance, during herring fishing on spawning grounds, fishermen are using large trawls which are not permanently towed, but are set towards fish detection located by means of sonar and sounder. Twines in the fore part of the net are relatively thin, only those in the aft part are reinforced.

Smaller and stronger trawls are preferred for fishing cod, whiting and coalfish, in relation to the longer duration of the tow and their closer contact with the bottom.

Finally, smaller trawls with elongated shape and made of thin twines are used for inshore mackerel trawling which requires a high towing speed (in excess of 4 knots). In each case it is possible to relate the net dimension and the towing speed to the trawler horsepower.

To conclude, the terms semi-pelagic trawl and high-opening bottom trawl apply to a variety of nets which have an important opening height as a common characteristic and which are related not only to the vessel horsepower, but also to the different species sought.

The Use of Electronic Aids in Trawling

C. H. G. Drever

L'emploi des aides électroniques en chalutage

Avec la diminution des stocks de poissons sur les lieux de chalutage traditionnels, l'application des aides électroniques à la pêche présente une importance accrue. L'expérience acquise pendant 8 années de commandement à bord d'un chalutier à pêche arrière congélateur de 73 m (240 ft), sur les fonds de l'Atlantique nord, prouve que les écho-sondeurs pour la détection du poisson, les aides à la navigation et l'équipement auxiliaire contribuent dans leur ensemble à l'efficacité. En particulier, le système de détection du poisson "Humber" a été utilisé pour étudier le comportement en banc et le mode de distribution de la morue à proximité immédiate du fond sur divers lieux de pêche, ainsi que pour observer les effets des modifications du cap et de la durée du trait en vue de l'obtention du meilleur rendement de capture. De petites modifications ont été aussi apportées au petit modèle de chalut Granton afin de l'adapter à la répartition du poisson. Un appareil de mesure de la tension des funes, employé à bord des chalutiers à pêche arrière britanniques depuis un petit nombre d'années, s'est révélé comme un dispositif d'alerte précieux quand le train de pêche est croché; il a fourni également des informations additionnelles en ce qui concerne la nature de la croche et les avaries subies par le chalut. D'autre part, on emploie cet appareil pour déterminer le nombre convenable de tours-moteur afin d'obtenir l'efficacité maximale de remorquage. Le Decca Navigator et le traceur de route ont prouvé leur utilité dans la pour-suite d'une route donnée dans des régions de profondeur uniforme où le poisson tend à se grouper dans des secteurs particuliers. Le Loran présente l'avantage de fournir une couverture complète des fonds, mais il réclame d'avantage de temps pour obtenir un point. Un certain nombre de cartes carroyées utiles sont disponibles pour la région du Labrador. La radio-goniométrie rend le plus souvent des services dans les secteurs situés au-delà de la portée vers la terre du radar. L'emploi du radar est profitable lors qu'il s'agit de déterminer la vitesse et la répartition des autres bateaux sur les lieux de chalutage, ou de contacter les autres pêcheries en changeant de secteur. On peut inclure parmi les aides dont la mise au point est en cours, la manoeuvre contrôlée de la barre, le comptage automatique des poissons et la télémétrie acoustique.

El empleo de los medios electronicos en la pesca al arrastre

Al disminuir las poblaciones en los caladeros de pesca al arrastre tradicionales, ad quiere más importancia la aplicación de medios electrónicos en la pesca. La experiencia obtenida durante más de 8 años como patrón de un barco a bordo de un arrastrero por popa y congelador de 240 pies (unos 73 metros) de eslora, en los caladeros del Atlántico Norte, ha mostrado que contribuyen a la eficacia en la pesca las ecosondas para localizar peces, los auxiliares de navegación y el equipo accesorio. En especial se ha empleado el sistema de localización de peces "Humber" para estudiar la formación de cardúmenes y cómo se distribuye el bacalao cerca del fondo del mar en varios caladeros, y para observar las consecuencias de las modificaciones en la dirección y duración de los lances, con objeto de obtener las mayores capturas. Se efectuaron ligeros cambios en la red de arrastre pequeña Granton para adaptarla a la distribución de los peces. A bordo de los arrastreros por popa británicos se emplea en los calles de arrastre un dinamómetro que es un instumento de aviso cuando la red se engancha, y ha dado información adicional acerca del modo en que se ha enganchado, y sobre el daño sufrido por la red. Se ha empleado también para determinar las revoluciones del motor para lograr la máxima eficacia de arrastre. El navegador Decca y el trazador del rumbo han demostrado que sirven para seguir una cierta ruta en regiones de profundidad uniforme en donde los peces tienden a concentrarse en determinadas zonas. El loran tiene la ventaja de que abarca todo el caladero, pero se necesita más tiempo para obtener una marcación. Existen útiles cartas reticulares de la zona del Labrador. El radiogoniometro es utilísimo donde el radar no aleania la costa. Se puede emplear radar para observar otros barcos para determinar como pescar al arrastre y sus velocidades, y para entrar en contacto con ellos cuando se cambia de caladero. Entre los medios electrónicos que se perfeccionan actualmente, y que es probable que sean útiles, figuran los timones controlados, contadores automáticos de peces y la telemetría acústica.

THE need for maximum application of electronic aids to trawling is becoming more important from year to year. With steadily diminishing fish stocks on traditional grounds and gloomy forecasts from marine biologists, it is essential to maintain optimum fishing. To this end various electronic devices aboard the modern sterntrawler play a large part and in some cases benefits derived are greater than was originally visualized. Fish detection echo sounders, navigational aids and specialized auxiliary equipment, all contribute to overall efficiency, particularly when fishing as a single unit on unknown grounds. The interpretation of fish detection echo sounders in recognition of schooling pattern and distribution of fish on a particular ground is most important in terms of gear adaptation and of direction and length of tow. Use of pure navigational systems for position keeping whilst fishing is also essential and automatic steering devices remove part of the load of the physical aspect of fishing. The conclusions drawn from personal experience gained using various equipments over the last eight years aboard a 240 ft (73 m) sternfreezer trawler in the North Atlantic cod grounds are here described.

INTERPRETATION AND USE OF ECHO SOUNDERS FOR FISH DETECTION

The experience gained has been in use of Kelvin Hughes "Humber" Gear. With its unique triggered pen presentation which gives a paper record of echo traces seen on the cathode-ray tube scale-expander, it is possible to study in detail schooling pattern and distribution of fish near the sea bed over any grounds.

The way in which cod distribute themselves over a fishing ground varies considerably from one bank to another. On any one ground, particularly one accepted as either a daylight or a dark fishing area, this pattern can change from season to season. For example, the cod may spread in a series of large compact groups with no individual fish between them; they may spread in a continuous layer on the sea bed in a more widely spaced fashion; they may be present in small groups which are linked by individuals, or they may be singly and evenly distributed over a wide area.

Accepting that cod distribution behaviour changes, there are certain grounds which have a fairly regular pattern. It is useful to discuss some of these, picked at random,

which are typical of many others with respect to distribution and daily movements of fish.

Fish spread out

The Woolfall area on the Grand Banks off Newfoundland is a daylight fishing ground most times. In reasonable conditions, towing times of one to two hours during daylight are extended to four hours during darkness. Despite long night tows, one can expect only about one-third of the weight of fish caught in a daylight haul.

On this ground, one would expect the fish to be reasonably widely spread in small groups, interconnected by single fish. This type of ground requires close scrutiny of the C.R.T. (cathode-ray tube display) and triggered-pen record. It is virtually impossible to "loop" the ground, i.e. search the ground with the fish detection echo sounder before shooting. The fish are so close to the sea bed and so well distributed that it is only with difficulty that an assessment of the potential of the ground can be made, even at slower speed of towing.

Apart from echoes from small groups of fish, indications on C.R.T. are mostly just a brightening of the top of the sea bed echo either side of the vertical time-base line (fig 1).

This brightening occurs on five or six consecutive occasions for each single fish at towing speed, whereas at full speed this would be reduced to one or two indications per fish. The triggered-pen record (fig 2) will also show very small spikes on the sea bed line, perhaps an eighth of an inch (3 mm) in height, these being sometimes spread throughout the whole tow in close proximity to each other. However, more often, blank periods on the triggered-pen chart indicate wasted parts of the tow.

The triggered-pen record is examined after each haul to determine the most prolific sections of the tow. Modifications are made to subsequent tow in direction and position, so that it coincides with the heaviest

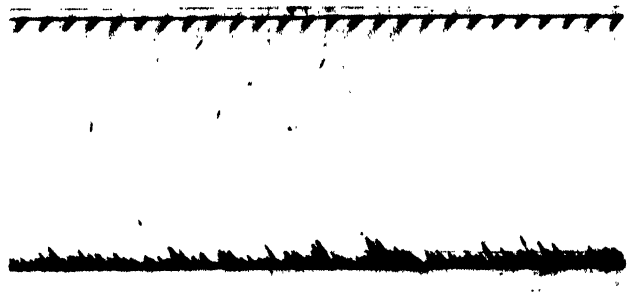

Fig 2. Triggered pen record of ship's echo sounder showing individual codling evenly spread close to sea bed. Woolfall area: 80 fm (about 146 m). catch rate 80 baskets/hour (about 3.600 kg/h)

concentrations previously recorded. If it is apparent that the majority of the fish were caught during the first part, it is advisable to steam back over the barren section and shoot into the more productive area, probably extending the tow in that direction if the fish traces warrant it. Otherwise, a quick come-round or back-round to cover the most abundant area twice during a tow may be more profitable. If, however, the triggered-pen recorder chart shows better fishing in the latter part of the tow, the best system is to steer for 5 or 10 min in the direction of the previous tow and then shoot back in the opposite direction. This is to ensure that the gear is settled by the time the vessel gets to the previous position of fish marks.

At the end of the first tow on such a ground, a comparison between the triggered-pen fish marks and the number of fish caught sets the standard for future estimation of daylight catches on that ground. Having established what the hourly catch rate looks like on the triggered-pen record, this factor can be used as a guide to expected hauls in succeeding tows. Adjustments may be necessary to the tow's length.

If the fish echoes should appear more easily recognizable on the C.R.T. (fig 3) with possibly two or more

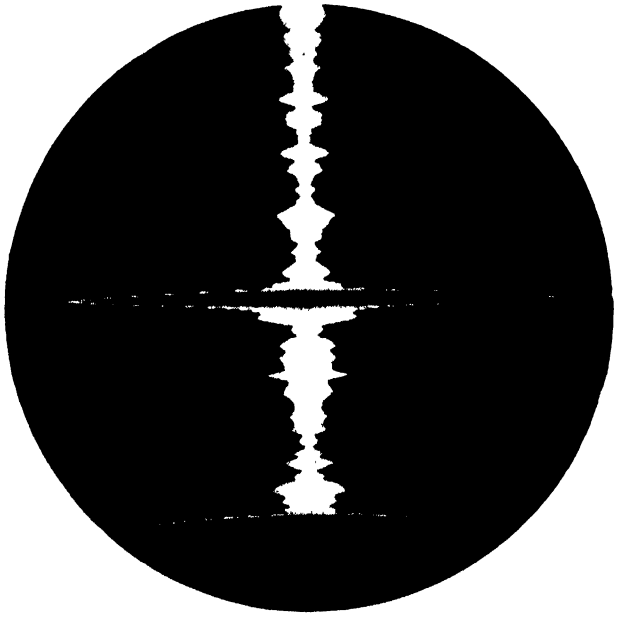

Fig 1. Cathode ray tube (CRT) display of ship's echo sounder showing single fish nearly 2 fm (about 4 m) off sea bed: brightness on top of sea bed echo indicating fish hard down. Scale, 0 to 4 fm (about 0 to 7 m) above sea bed

Fig 3. CRT display of ship's echo sounder showing single fish clear of sea bed and multiple echoes from several fish merging with sea bed echo

echoes superimposed on one from the sea bed echo, heavier fishing should be expected provided the bottom of the fish echo merges with the sea bed echo and generally tends to get bigger at the point near the latter. The moment there is a gap between the fish echoes and the sea bed echo, this indicates that the fish are not tight on the sea bed and that less value can be placed on this echo. This effect would be expected to be seen just before dusk.

Fish in groups

The Nanortalik Bank, off the southwest corner of Greenland, is another area where daylight fishing prevails. However, in direct contrast with the Woolfall area, Nanortalik is a fishing ground which invariably consists of large dense concentrations of cod with few single fish between. Here the duration of tow varies considerably from haul to haul and is directly related to the number, extent and density of concentrations of fish.

Once again, the decision regarding how to tow is governed by what is seen on the C.R.T. and the triggered-pen chart. If one is lucky enough to have just settled the gear immediately prior to arriving over a dense concentration of fish of suitable extent, a towing time of 20 min will often suffice for an extremely heavy haul. At times, it has been necessary to haul while still recording heavy fish marks in order to avoid damage to the trawl either from excessive weight of fish while on the sea bed, or by losing the codends when attempting to heave a huge catch up the ramp.

This hauling while still on fish is influenced by previous experience and one has to learn to assess the magnitude of the trace on C.R.T., the density and extent of the marks on the triggered-pen chart and the closeness of the fish to sea bed.

These concentrations of fish can extend in height over 5 fm (9 m) from the sea bed and their echoes can com-completely obscure the time-base line of C.R.T. from the sea bed to the top of the tube. The triggered-pen chart shows a continuous black mark which covers the complete record at times (fig 4).

Fig 4. Triggered pen recording of ship's echo sounder showing clumps of codling off Nanortalik Depth, 70 fm (about 128 m): catch 150 baskets (about 6,800 kg): scale 0 to 4 fm (about 0 to 7 m) from sea bed

When fish are in densest concentrations, their echoes are so strong that stabilized displays of the echo sounder behave in an erratic manner. This requires a reduction in the sensitivity of the apparatus from its normal setting to produce stability so that the lower extent of the fish echo can be examined to make sure that it is "hard down" on the sea bed echo. If this is so, the necessity to make this sensitivity adjustment is a good indication of very heavy fishing.

At times the distances between concentrations is such that one can be unfortunate enough to tow between them and have a more or less blank haul. Even when acting upon immediate genuine information from another trawler in close proximity, to the effect that he has just passed over one of these concentrations, one can manoeuvre quickly to follow directly astern of him, only to find that on arrival at the original position of the concentration the fish are no longer there. Equally, when one has hauled shortly after towing through the area of a heavy mark and accurately shot back on a reciprocal course, one finds the ground barren.

These fish must therefore change position remarkably quickly, this probably being brought about by the scaring action of the trawl. Engine noise is unlikely to produce this reaction as the water is not shallow; also at times it is possible to shoot back into a dense concentration which has been recorded just previously when looping the ground.

In fact, it is common practice when having lost contact with the concentration of fish to steam around the area searching with the fish-detection equipment in operation. Once having fixed the position of the concentration, the trawl is shot straight towards them.

Fish along a depth contour

The northeast corner of the Grand Banks at Newfoundland is, once again, a ground that is typical of many others. The ground slopes gently from 80 to 170 fm (146 to 311 m) and then drops away more sharply and the majority of the fish tend to lay along one depth contour at any time. As a general rule, over 170 fm (311 m) is bad ground but there are little areas where a tow may be made as deep as 220 fm (402 m). Otherwise it is one of the finest grounds of Newfoundland.

It is often a successful procedure on this ground to start off from the first daylight haul in 110 to 115 fm (201 to 210 m). The trawl is shot and the water slowly deepened until fish indications are observed on the C.R.T. and triggered-pen recorder chart. The depth contour of that water is then followed until the marks tend to give out. The vessel is then taken deeper until the fish indications increase again and that depth of water is held for as long as the marks are recorded, working yet deeper when they disappear. The depth fished may vary by as much as 20 fm (37 m) during the course of the two-hour tow. If one has a successful haul, the trawl is shot in the hauling depth and the working depth is gradually increased throughout the tow, as before. One has to be careful not to proceed too deep too quickly, thus overshooting the movement of the fish. Having started working in 110 fm (201 m) at the first daylight haul, it is not uncommon to find oneself working in 170 to 220 fm (311 to 402 m) at the dusk haul.

The triggered-pen record shows a more or less continuous trace of single echoes, merging with each other at times and extending for about a fathom (2 m) off the sea bed. These may continue for about a mile (2 km) or so, in any one depth before one has to alter course to move deeper into the water and pick up the fish again.

This ground is ideal for using the fish-detection equipment, being very gradually shelving with no steep edges except in extreme depths.

Due to the fine nature of the ground and the excellent fishing which occurs at times, this is a popular area for trawlers of all nations, particularly factory ships which are fed by a fleet of small trawlers.

Use of floats and bobbins

The standard small Granton trawl is used by the majority of British sterntrawlermen.

For cod trawling, the number and type of floats used on the headline varies. Around 50 single floats are usual, with 20 in the bosom and 15 in each wing. Variations are made with the use of the double Siamese twin floats and top hats.

If the fish-detection displays show the fish to be slightly up from the sea bed, the addition of six Siamese twin floats placed at regular intervals along the headline to supplement the standard 50-float rig will raise the headline a critical few inches. An improvement of 10 to 20 per cent in the catch rate has been obtained by this means. This has been particularly noticeable on grounds where the fish have been in concentration or in a continuous formation along the tow from the sea bed to about 2 fm (4 m) up.

Conversely, if the fish are then observed to be settled closer to the sea bed, an improvement has been effected by the removal of these extra floats, thus bringing about a slightly increased spread which is better suited for this situation.

Bobbin size can sometimes have a profound effect on catching rate. When a 24 in (61 cm) rig has been used on a ground where the fish are observed tight down to the sea bed a change to the 21 in (53 cm) gear has often brought about a doubling or even trebling of catch rate. This is a proven fact and it seems quite extraordinary that the difference of a few inches in bobbin diameter should bring about such a great change in catching performance. This has been experienced many times, particularly at the northeast corner of the Grand Banks where long bridles are normally used in conjunction with smaller bobbins. The use of longer bridles entails a slight increase in towing power in order to maintain the trawl at its most efficient state.

The main reason for the use of the 24 in (61 cm) bobbins is, of course, to minimize belly damage on rough ground, and the large rig is used with shorter cables.

USE OF WARP-LOAD METERS

Warp-load meters (e.g. the W.F.A./Kelvin Hughes system) have been in general use aboard British sterntrawlers for the last few years. Despite the possibility of slightly increased warp wear due to the additional sheave, this device has proved to be of great benefit.

The warp-load meters give most assistance when the trawl is actually fast to the sea bottom or when there is some obstruction. However, information can be gleaned from the instrument concerning the state of the trawl with particular reference to parted headline legs or square damage.

One type of fastener occurs when the ship slowly comes to a standstill, the doors having dug into a muddy sea bed, piling a heap of mud before them, thus gradually slowing the vessel down. What has happened is obvious from the state of the doors and perhaps the danlenos when they are hauled in.

The warps do not usually pull out in this case. The ship's log or visual observation of the speed of the vessel through the water will give obvious indications of the situation but there are times when the lone person on the bridge has other duties which absorb his attention. As this type of fastener almost invariably leads to damage to the belly of the trawl, the meter's siren warning of increased load and prompt action in stopping the propeller reduces the extent of damage and may avoid it altogether.

Although the positions of fasteners are always carefully plotted by skippers, the type referred to, which can also occur on stony ground, is not worth noting as it relates to the general nature of the ground and may occur at any time. Weight of doors, direction of tow, and state of tide will undoubtedly contribute to whether one comes fast.

A second way of coming fast occurs when one side of the trawl is momentarily snagged, at times without pulling the warp out. The result of such a snag is usually the parting of a headline leg or, worst still, the headline itself. In either case, the trawl is no longer fishing and if the headline is parted, the longer the tow continues in this state, the worse the total damage to the net. One warp-load meter will register an increase of 2 to 4 tonf (about 20 to 40 kN) above the normal reading at the time of catching the ground and this then falls quickly back to about the usual level. If damage has occurred to either headline leg or headline, near the wing end, one meter will read about $\frac{1}{3}$ tonf (about 3 kN) less than previously shown. There may be a slight indication of increased speed on the log but this is difficult to detect when variations in tide etc. produce long changes of similar or greater magnitude.

In bad weather, this small reduction of warp tension is imperceptible owing to the mild fluctuations in load when the trawl is in normal operation. However, much valuable towing time has been saved by hauling when a snag has been indicated and this slight difference noted.

Sudden type

The third case is the unmistakable dangerous fastener where the alarming scream of one or both warps paying out against the brakes is warning enough. Although the warp-load meters are not required to indicate that the trawl is fast, this is the case in which maximum benefit may be derived from them, when the normal practice for clearing such an obstruction is put into operation.

After immediately stopping the vessel, hauling commences, the ship being pulled astern towards the obstruction with the slack warp being taken up at speed until excessive strain is shown on the load meters, when the remaining warp is more or less straight up and down. Under these circumstances the meters may show that the gear is snagged on one side only, or equally caught on both sides. This is the crucial moment when total loss

of gear or extreme damage can take place. Having this information, regarding the strain on each warp, can give a useful picture of what has happened down below and allow the best method of clearing the obstacle to be used.

It may be found necessary to heave slowly on one warp, at the same time slacking away on the other in order to pull the gear clear, if there is a high reading on one meter of say 10 tonf (about 100 kN) and a low reading of 3 to 4 tonf (about 30 to 40 kN) on the other. No two situations of coming fast are alike and the course of action taken has to suit each individual case, taking weather and tide into account.

Parted warp

Once the gear is clear of the obstruction, the warp-load meter readings tell one if it is still attached to both warps, in which case the normal hauling readings are obtained. If one cable has parted, readings of probably 2 tonf (about 20 kN) on the parted side and 5 to 7 tonf (about 50 to 70 kN) on the other, will confirm that the gear is still attached by the cable to the high reading side. An equal low reading of 2 tonf (about 20 kN) on each side is reason for despair.

In both the last two cases, an increase in speed of the vessel over that which is normal when hauling will be observed. Sterntrawlers are particularly susceptible to locking their doors when clearing a fastener especially with a fresh strong wind afore-side of the beam on the original course. This has to be taken into account when assessing the warp-load meter readings on hauling, after coming fast.

Setting engine revolutions for towing

When a trawl is towed by a powerful sternfisher at the correct speed for maximum catching efficiency, the skipper is well aware that this is close to the point where the gear will lift off the sea bed and any error in setting the towing engine revolutions too high will bring this about. When towing into the wind, the revolutions must be increased in order to cover the ground properly, and fear of floating the gear makes one underestimate the increase which is required, perhaps three to four revolutions per min being added where in fact an increase of ten or more is necessary. The indications of this are a falling off of speed and reduction of warp-load meter readings when meeting a head sea, which must produce a distortion of the net. The method of arriving at the correct towing engine revolutions is to increase them until the regular warp-load readings for the prevailing conditions are obtained. The low warp-load readings may be due to towing too slowly or floating the gear but it is immediately obvious which of these two situations is the case.

AIDS TO POSITION KEEPING

The Decca Navigator system is an invaluable item of equipment on any modern trawler bridge. Unfortunately, the coverage does not extend over all Northwest Atlantic grounds. Greenland, for instance, has no coverage and the further north one goes on the Labrador grounds the more parallel the lanes become and therefore increasingly inaccurate for position keeping. However, there is excellent coverage for all areas south of the Belle Isle Gulley.

North Sea fishermen show great skill in towing between obstructions which have been accurately pinpointed by previous readings and charted over the years, these obstructions remaining more or less constant. However, on the Northwest Atlantic grounds there is the continual passage of icebergs which sometimes release huge boulders, and which on occasions run aground, thus scouring the sea bed and leaving a ridge. This means that new snags are continually appearing and the plotting and marking of these is another facet of the skipper's job. Charts of these areas are improving all the time but, as yet, there are no true fishermen's charts showing obstructions.

In many areas, there are large expanses of even depth. Here, the usual system of contour fishing is impossible. A further complication to position keeping is a permanent southerly current of up to 1½ kn (about 0.8 m/s).

It is sometimes found that on these even-depth grounds, and also on undulating grounds where depths do not vary by more than 5 to 10 fm (about 9 to 18 m), fish concentrations occur in a specific area. In these conditions it is often profitable to follow a particular lane, making appropriate alterations to counteract leeway. The associated Track Plotter is of great assistance here, as it eliminates need for time-consuming manual plotting and makes the job of repeating a tow comparatively simple.

Loran

Unlike Decca, Loran provides full cover of the North Atlantic and is essential when steaming to and from the fishing grounds.

Unfortunately, it takes time to obtain a Loran fix and time is not always available when fishing due to other pressing demands. However, in areas north of Belle Isle Gulley, that is the whole Labrador area, Loran coverage is particularly good. The recently published large-scale West German lattice charts of Newfoundland and Labrador areas are excellent.

In these areas trawling usually takes place along the depth contours, which run mainly north and south. Using Loran lanes, which lie roughly east and west, together with a depth contour, a good fix can be obtained.

At Labrador there are stretches of bad ground which can extend for 30 to 40 mi (about 56 to 74 km) and it is easy to be carried on to those areas if one does not make an allowance for southerly currents. Good position is therefore essential for avoiding rough ground and also for keeping in contact with the fish.

The Radio Direction Finder, whilst not in the same category as Decca and Loran for position keeping, is of importance, especially on some West Greenland banks, as a large percentage of these areas is outside radar range of land. A combination of a depth contour and one direction-finder bearing is the only method available for position fixing, apart from the use of a sextant.

RADAR AND OTHER OBSERVATIONS

So much has been said about radar, from the navigational aspect, that further comments are superfluous here. However, there are ways in which radar can be specifically applied to trawling.

There are times when one is the only vessel fishing amongst a fleet of trawlers of other nationalities. Because of language difficulties and the use of coded reports, it is not possible to obtain relevant information to allow proper evaluation of the fishing potential.

In these circumstances, radar observations are made, irrespective of visibility, to determine the overall towing pattern of the vessels. If one is aware that these vessels are closely cooperating with each other, any change in existing pattern is likely to be brought about by their conclusions drawn from the intership reports. It is difficult to obtain a total towing picture purely by visual observation from the bridge window, whereas the radar C.R.T. gives an immediate and precise plan-view. For instance, if the fish are laid along a depth contour, this will be apparent from the fact that the vessels are in a single line and obviously following a particular depth of water. If the fish are laid narrowly in one depth or the gradient of the ground is steep, the vessels will often agree to tow in one direction only, steaming back at the end of each tow clear of the ships. This minimizes the risk of collision and enables an exact depth to be maintained during towing. If the fish then tend to spread out, or the catch drops, this is quickly reflected by the change information of the ships. A general scattering is observed until a favourable report has been given out, when they reform into a definite formation.

Then there is the case where one vessel is observed repeating its tow continually inspite of being aware of the catch rate of the main body of ships. The fact that this vessel remains alone is a fair indication that the catch rate in that position is as good as, if not better, than that of the main group.

Moving grounds

Without reference to the radar screen, it is not always apparent that vessels are leaving the area. By radar observation one becomes aware of the gradual diminution of numbers, the likely cause of this being a report of more productive fishing elsewhere. Close radar watch is then kept on the vessels to ascertain the course of those ships which haul and steam. Although the course is then known the distance to be steamed is still not established, except in some cases where it is obvious that there is only one ground in that direction. When fishing close to ice-fields, the sudden steaming of a large number of vessels is sometimes an indication that the area is being encircled by ice. At the appropriate time of year for a specific ground, this situation can develop and is something which must always be kept in mind. Radar is of immense value when looking for the best way out of the ice, indicating the leads, density and possible extent of the fields.

Because of the wide area of fishing grounds in Newfoundland and Labrador area, it is not uncommon to have to steam for 36 h or more when changing grounds. In fact, with the large fish-room capacity and consequent longer voyages of the sternfreezer trawler, it is not unusual to change grounds from Greenland to the Newfoundland/Labrador area and vice versa during the course of the trip.

When a decision has been made to steam to a distant ground the time lag is such that when one arrives at the previously reported position, the fish, and therefore vessels, may have moved by as much as 50 to 60 mi (about 93 to 111 km). Ideally, one has constant contact with the reporting vessel and may obtain a series of D/F bearings, but this is not always possible. If not, it is advisable to maintain a constant radar watch for four to five hours prior to arrival at the last reported position.

If in fact these vessels have moved to keep contact with heavy fishing, it is very often possible to locate them at ranges of up to 40 or 50 mi (about 74 or 93 km) by reception of their radar transmissions, which appear as a series of interference dots on the ship's radar display, giving the bearing of the transmission but not the range. The number of interference lines is indicative of the number of vessels operating radar in the area.

Towing speed

Another trawling application of radar is to check one's towing speed against another vessel, the towing performance of which is known. It happens at times that although the fish are spread out fairly evenly over the ground, the catch rate of one vessel is not comparable with that of others on the same ground. This can be due to many factors, one of which is increased speed over the ground. By towing dead astern of the other vessel and setting the range-marker ring to coincide with the echo from that ship, one can easily ascertain whether or not the leading ship is being overtaken and, if so, at what rate. Allowing for any normal towing differences between the two ships, an estimate of towing speed can be made.

SOME POSSIBLE FUTURE AIDS

The array of instruments confronting the skipper and the number of different actions that have to be performed by him makes the job of trawling exceedingly complex. There is a requirement for the removal of as many basic chores as possible in order to allow the skipper to use a higher degree of concentration on those items which can produce greater fishing efficiency.

The automatic gyro-controlled steering system is of undoubted immense value to the professional modern fisherman but if this were coupled to the echo-sounder information so that the vessel would automatically follow a depth on grounds where contour fishing is the rule, it is thought that this would be a definite advantage. A further thought on these lines is the possible use of the Decca Navigator system when "lane touring" to control the vessel's course on the selected lane. Again, perhaps a system could be devised to repeat automatically a tow previously recorded by the Track Plotter.

An accurate automatic fish-counting device, which would give displays in terms of catch rates over a period and total catch, would assist in the maximum exploitation

of the grounds and prevent unnecessary hauling when working fine grounds.

It is possible that some or all of these ideas have already been tried and the cost has been prohibitive.

Telemetry, as applied to fishing, is only in its infancy. What a tremendous benefit it would be if skippers had exact, relevant information of gear performance, such as door spread, headline height and possible damage! Much time could be saved and thus more profitable fishing achieved.

Acknowledgement

Acknowledgement is due to *World Fishing* for permission to reproduce the figures.

Instrumentation for Fishing Gear Experiments

L. D. Lusz

Instruments pour l'essai des engins de pêche

On a mis au point divers instruments pour mesurer avec précision les paramètres du fonctionnement des engins de pêche. Ces instruments fournissent des données sur les dimensions du chalut, la profondeur de chalutage, la tension de charge sur chalut, la tension de touage au bateau et la vitesse de trait de ce dernier. Un câble de trait électromécanique et un cordage à âme électrique ont été utilisés avec succès pour transmettre les données du chalut au bateau de pêche. Les résultats sont présentés dans la passerelle au moyen d'enregistreurs à bandes ou de compteurs. Pendant les deux dernières années, on a recueilli des données provenant de divers chaluts à bord du *John N. Cobb*, bateau de recherche d'une puissance de 350 CV. Ces données permettront de mieux comprendre le fonctionnement des chaluts pélagiques et de fond utilisés par les pêcheurs de la région nord-ouest du Pacifique.

Instrumentos para artes de pesca

Para medir exactamente algunos parámetros de las artes de pesca en acción se han construido varios instrumentos que permiten obtener datos sobre las dimensiones de la red de arrastre, la profundidad a que trabaja, la tensión de carga en la red, la tensión del cabo de remolque en la embarcación y la velocidad de remolque. Para transmitir los datos de la red al barco de pesca se han empleado con éxito cables de remolque electromecánicos y cabos cuya alma es un cable eléctrico. La información puede leerse en la caseta del timón en registradores de banda o en contadores. En los dos últimos años se han obtenido datos sobre diversas redes de arrastre en al *John N. Cobb*, barco de investigación con motor de 350 hp. Los datos obtenidos permitirán entender mejor el funcionamiento de las redes de arrastre pelágicas y bentónicas empleadas por los pescadores del noroeste del Pacifico.

IN 1957, the Bureau of Commercial Fisheries Exploratory Fishing and Gear Research Base at Seattle, Washington, began a programme of developing instrumentation to measure the performance of experimental and commercial fishing gear (fig 1).

A double-armoured electromechanical cable designed for oil-well logging was tested aboard the Bureau of Commercial Fisheries' exploratory fishing vessel, *John N. Cobb* (McNeely, 1958). The tests proved that the cable was not reliable because of problems such as "bird caging" of the armour, breakage of electrical conductors, failure of electrical connections, and failure of cable terminations. It was shown, however, that electromechanical cable could be used to tow a trawl and transfer data from trawl to vessel.

IMPROVED ELECTROMECHANICAL CABLE

To improve reliability, the design of the cable was changed (Lusz, 1969). The modified cable had four concentric layers of galvanized steel armour with strands of alternate layers wrapped in opposite directions to produce a torque-balanced cable that would not twist and unwind. The additional layers of armour increased the outer diameter of the cable to 0.66 in (1 68 cm) and the breaking strength to 47,000 lb (21,350 kg) The layers of armour were impregnated with a corrosion resistant material to increase cable life. The configuration of the electrical core was changed to include a cotton centre filler and sheath for increased flexibility and to relieve internal strain. Insulation of each conductor was a polypropylene and nylon sheath combination. The pitch diameter of the towing blocks was 20 in (50.8 cm). This combination of oversized sheaves and modified cable configuration has proved satisfactory during subsequent tests.

Mechanical terminations

Initially, terminations to towing end of cable were made by curling armour strands and retaining them within a socket with babbitt (McNeely, 1963). This type of termination was not completely satisfactory as the molten babbitt was difficult to prepare and use. The termination would pull apart if the babbitt did not adhere to the armour strands. The electrical conductors were easily damaged by careless workmanship.

During tensile tests in the laboratory of different methods to terminate the cable, it was discovered that curling individual armour strands produced a weaker termination than when strands were not curled. An epoxy compound composed of 80 per cent iron filings provided the strongest terminations of all materials tested. Because of the high compressive strength of metal-filled epoxy, it did not tend to extrude from the socket or crack under high loads as much as standard epoxy or babbitt. Two terminations made of the metal-filled epoxy and non-curled armour strands were tested to the rated breaking

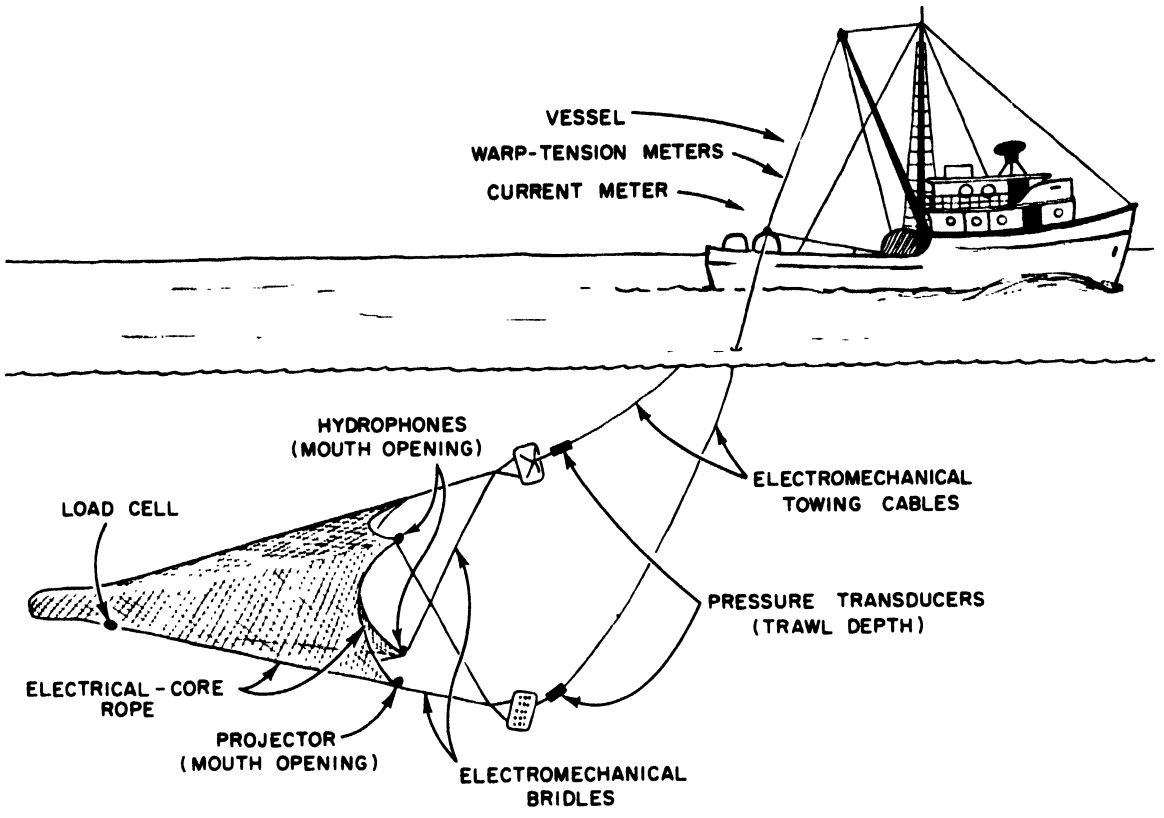

Fig 1. Diagram showing the relation between vessel, trawl, cables and instrumentation

strength of the cable. Additional tests in ocean environment proved this termination to be satisfactory for research and commercial operations. Terminations are small, rugged, and simple to install. To ensure reliable service, the cables are reterminated once each year.

Preformed "Guy-grips"*—gripping devices that develop low unit pressure over a relatively large area to produce a high total force have been successfully used to mechanically terminate electromechanical cable. They are wrapped onto the cable by hand with the cable terminated within the Guy-grip or continuing through the Guy-grip as desired. They are primarily used in emergencies or with an otterboard by-pass system—described later.

Cable clamps are used to terminate the electromechanical cable on the vessel winch. This technique is the same as that used with regular towing cable, except that clamps are tightened only slightly so as not to damage conductors.

Electrical terminations

Factory-moulded, field-installed underwater connectors are used on the cable. Instrumentation transducers are constructed with watertight bulkhead connectors so they can be interchanged on the cable quickly and easily.

The electrical conductors at the winch end of the electromechanical towing cable are terminated with waterproof connectors and a short rubber covered jumper cable which is attached to the flange of the winch with straps. When telemetry is used, one end of the jumper cable is disengaged from a retaining strap on the winch and connected to a factory-moulded waterproof cable that extends into the pilothouse. This method does not allow continual monitoring of the trawl instrumentation as the jumper cable must be disconnected when the winch is operated. As the jumper cable is sometimes subject to abuse, it is connected to the towing cable conductors with field-installed connectors so it can be replaced easily and quickly.

Principal commercial application for electromechanical cable is transferring information from otterboards to vessel; research engineers and commercial fishermen may also require data from the trawl. Therefore, a by-pass system around the otterboards was developed to form an electrical and mechanical connection between main towing cable and bridle (fig 2). The by-pass system was designed so that the bridles and trawl could be quickly disconnected from otterboards and placed on the net reel in a conventional manner. Consequently, by using a section of electromechanical cable for a bridle, information can be transmitted from trawl to vessel.

Electrical-core rope

Early experiments to obtain data from various locations on a trawl were often unsuccessful because of problems with the data link that connected the bridle to the mensurative transducer. Conventional rubber-covered cable tended to abrade and fail prematurely, especially when placed on a net reel. Electromechanical cable distorted the configuration of the trawl and was difficult to handle because it was stiff and heavy. To alleviate

* Trade names referred to in this publication do not imply endorsement of commercial products.

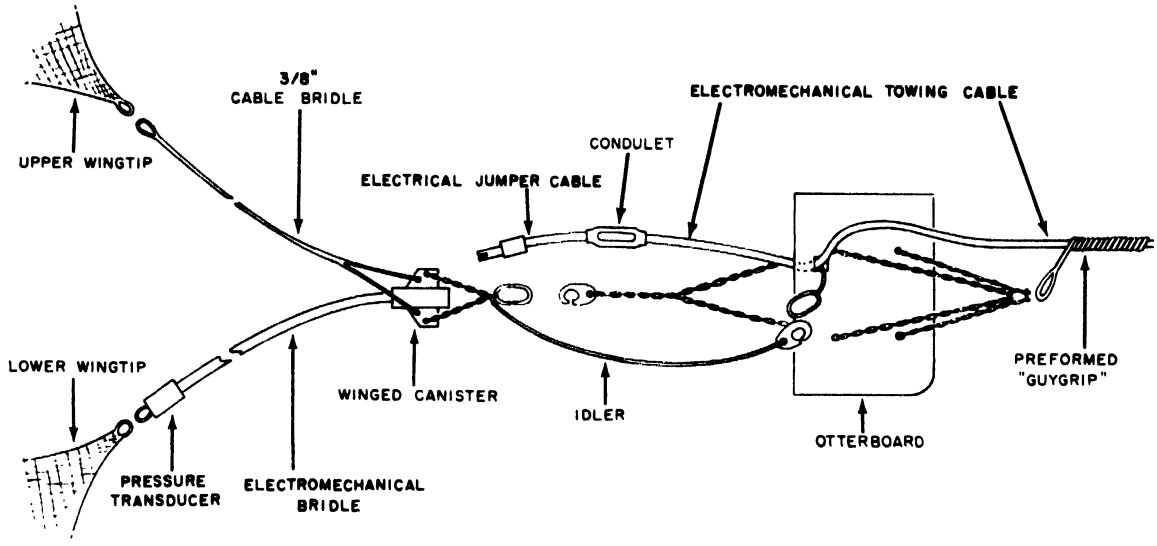

Fig 2. Otterboard by-pass system

these problems, an electrical-core rope was developed with properties similar to the ribline material used in the trawls.

In 1967, the electrical-core rope was successfully tested on a midwater trawl as a strength member and data link. Since that time, the rope has been used on many types of trawls to interconnect telemetry devices with an electromechanical bridle.

The rope had two concentric layers of braided nylon with an outside diameter of 0.688 in (1.74 cm) and a core of four electrical conductors. According to the manufacturer, breaking strength of the rope is 12,000 lb (5,450 kg). In laboratory tests, the electrical conductors failed at 75 per cent of the breaking strength of the rope when terminated with metal filled epoxy.

TRAWL INSTRUMENTATION

The pressure transducer of the depth telemetry system (fig 3) consists of a pressure-sensing element, voltage regulator, and amplifier. The transducer is precisely calibrated so that the magnitude of its output—0 to 1 V dc full scale—is exactly proportional to the applied pressure and enclosed in a hermetically sealed case at the factory. The bonded strain-gauge type pressure sensor is connected in a Wheatstone bridge configuration. The low-level bridge output voltage—0 to 50 mV dc full scale—is applied to an integrated circuit differential amplifier that provides the transmitter output signal. This amplifier has a low output impedance of 8 ohms, which is necessary to minimize signal deterioration due to any varying resistance of the conductors in the electromechanical cable. Final voltage control is provided at the transducer to ensure that a known excitation is supplied to both the amplifier and pressure sensor. During fishing operations, the transducer is enclosed in a canister on the end of towing cable for protection against damage (fig 4).

The readout unit presents transducer output voltage on either a voltmeter with a depth scale calibrated in fathoms or a digital voltmeter. Of the two types of units, the digital meter has greater accuracy, is easier to read, is more reliable, and increases system cost approximately 20 per cent. The strip-chart recorder is normally used only for research programmes as it is too expensive

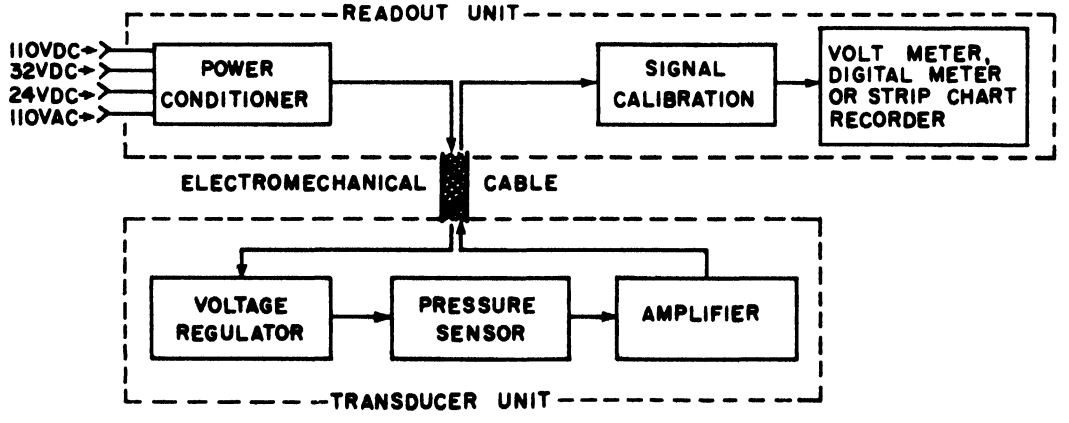

Fig 3. Block diagram of depth telemetry system

Fig 4. Exploded view of canister showing transducer and underwater electrical connectors

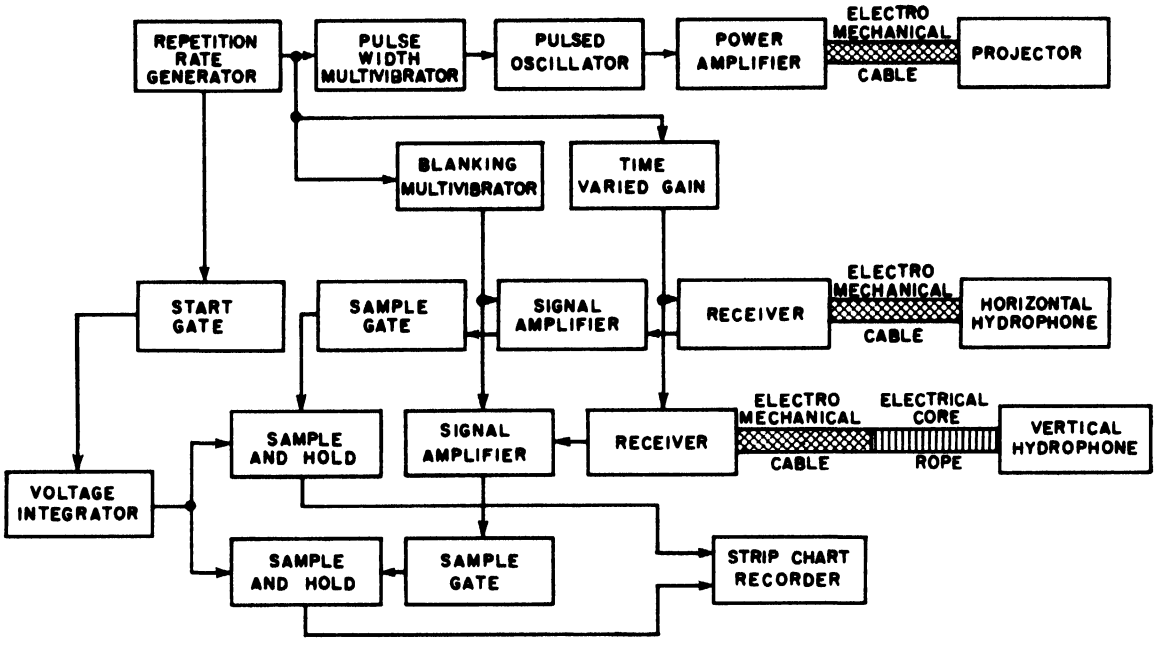

Fig 5. Block diagram of acoustic measuring system

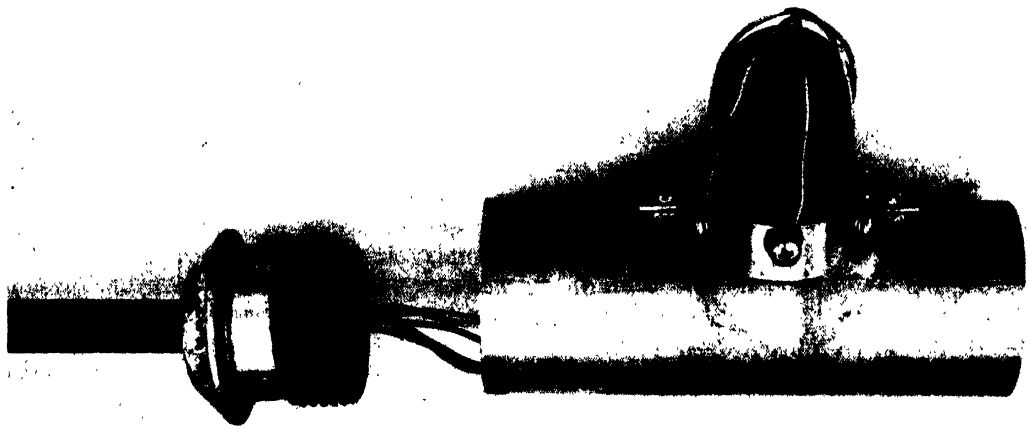

Fig 6. Wide-beam angle transducer of acoustic measuring system

for commercial application. Power conversion circuitry in the readout unit converts vessel supply voltages of 110 V ac, 110 V dc, 32 V dc, or 24 V dc to the transducer supply voltage. During fishing operations, the readout is calibrated to the vessel echo sounder. Consequently, a midwater trawl can be placed at the exact depth of fish concentrations as indicated by the echo sounder.

Acoustic measuring system

A trawl-mensuration system was specifically developed for research applications (fig 5). This sytem has been successfully used aboard research vessels to simultaneously measure vertical and horizontal wingtip openings of midwater and bottom trawls during fishing. It consists of a transmitter, receiver, strip-chart recorder, readout, and three wide-beam angle transducer (fig 6). A transducer is attached to each of the lower wingtips and one upper wingtip of the trawl to be measured (fig 1). One transducer (projector) is connected to the transmitter aboard the vessel by electromechanical towing cable and electromechanical bridle. The other two transducers (hydrophones) are connected to the receiver by electrical-core rope, electromechanical bridle, and electromechanical towing cable. The signal that is transmitted by the projector is received by each hydrophone and transferred to the receiver. The received signals gate the outputs of two voltage integrators into sample and hold circuits. The voltages, which are proportional to transducer separation distance, are simultaneously plotted on a two-pen electronic strip-chart recorder.

The transducers are of the quartz type. Each transducer has a diameter of 2 in (5.08 cm) and a length of 3 in (7.60 cm) and weighs less than 1 lb (0.45 kg). They have a half-power beam width of 180° at the operating frequency of 75 kHz.

The recorder can be calibrated for three ranges—10 to 100 ft (3 to 30.5 m), 10 to 300 ft (3 to 91.5 m), or 10 to 500 ft (3 to 152.5 m). System accuracy is 3 per cent of actual range.

Load cell

A system to determine load or drag on trawl components has been tested. The sytem generates a dc signal that varies linearly with applied tensile force. A strain gauge force summing member with an enclosed amplifier was inserted in place of a section of the ribline and the signal was transferred to the pilothouse by a combination of electrical-core rope, electromechanical bridle, and electromechanical cable. The data were plotted by a strip-chart recorder.

Although mechanical connectors failed during the test, the sytem was successfully used to determine the amount of fish being captured. Preliminary results indicated that load on the ribline increased as the amount of fish increased in the trawl. Additional field tests are planned to determine the feasibility of this system.

VESSEL INSTRUMENTATION

Two hydrostatic, deflection-type warp tension meters were installed aboard the *John N. Cobb* to measure the tension of the towing cables. The sensing unit consists of two pulleys on a frame which guide the towing cable across a third pulley. The third pulley displaces a hydraulic piston a distance that is proportional to the load applied by the cable. The piston creates a pressure that is transmitted through a high pressure hose to a meter read-out mounted in the pilothouse. The deflection of the calibrated meter indicates the tension in the towing cable. The readout has an audible alarm that sounds when a predetermined load has been exceeded.

The system has proven very useful for continuously monitoring warp tension but has several disadvantages. Calibration of the system changes with temperature which is not suitable for research purposes. Also, as tension is constantly changing and erratic at times due to adverse sea conditions, a strip-chart readout would be more useful than the meter readout.

Vessel speed in relation to water surface was measured by a ducted meter that is towed from the portside of vessel forward of propeller wash. The readout unit presents the meter output on a voltmeter with a scale marked in kots. This type of meter is relatively insensitive to vertical motion caused by rolling or heaving of vessel.

APPLICATIONS AND RESULTS

A total of 25 research and commercial fishing vessels have used electromechanical cable and depth telemetry in their respective fishing operations during the last six years. Since 1966, several United States vessel operators have purchased electromechanical cable and depth telemetry equipment, and pioneered a midwater trawl fishery for Pacific hake, *Merluccius productus* (Hipkins, 1967). During four years of continuous usage, two sections of cable were used for 1,110 tows. Although the original length of these cables has been reduced about 40 per cent, the remaining sections are still serviceable.

The acoustic measuring system has been used to ascertain the mouth openings of a 2/3 Cobb pelagic trawl, a 440 Cobb pelagic trawl, a 600 monofilament Cobb pelagic trawl, a 640 monofilament Cobb pelagic trawl, a standard 18 Cobb pelagic trawl, a 648 Cobb pelagic trawl, and a Mark I Universal trawl (Johnson and High, 1970). Each trawl was measured with vee-type and Cobb hydrofoil otterboards. The trawls were towed in mid-water through a series of different fishing conditions. A period of 3 to 7 minutes was necessary to allow each trawl to come to equilibrium for each steady-state measurement.

Horizontal openings increased for all pelagic trawls with increased engine speed or increased length of towing cable. Horizontal spread was less when the trawls were rigged with vee-type otterboards. As much as 20 per cent reduction in spread was attributed to the combination of shorter length of towing cable needed to fish at comparable depths and lower spreading efficiency of the vee-type otterboards over the hydrofoil otterboards. At constant vessel speed and constant length of towing cable, horizontal openings varied by as much as 7 ft (2.14 m), whereas vertical openings varied by as much as 4 ft (1.24 m).

Measurements for comparing mouth openings of trawls operating at diving depths and fishing depths have

been obtained. Historically, measurements obtained by diver-scientists at shallow depths have been used to estimate mouth openings of many trawls at fishing depths. The acoustic measurements showed that horizontal openings increased on all trawls by as much as 20 per cent when trawls were operated with increased lengths of towing cable in deeper water. Vertical openings varied from a decrease of 5 per cent to an increase of 15 per cent.

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New Types of Multi-netsonde Equipment

W. Horn

Nouveaux modeles d'equipement en multi-netzonde

A son origine, le netzonde fournissait les informations requises sur la profondeur du filet, la hauteur d'ouverture, le comportement du poisson dans la gueule du filet, etc. Par grande profondeur, quand le fond ne pouvait pas être détecté facilement, les appareils étaient tournés vers le haut, en direction de la surface, mais cette façon de procéder créait des problèmes quand on s'approchait du fond. On a alors introduit des projecteurs couplés pouvant sonder à la fois vers le haut et vers le bas. Une autre étape dans l'évolution de l'engin vit l'addition de deux autres projecteurs, dirigés vers l'avant, pouvant fournir des indications de droite à gauche ou dans le plan vertical, afin de diriger le chalut avec plus d'efficacité vers le banc de poisson. Les positions relatives du filet et du banc apparaissent sur un tube cathodique. La télémesure de la température de l'eau est un complément plus récent; un autre type de multi-netzsonde, appelé "Polynetsonde", comporte un circuit de stockage Video qui peut fournir une représentation par "image stabilisée". Un système de netzsonde à multi-projecteur, portable et de petite dimension, fonctionnant sur des batteries au lieu de l'alimentation électrique du bord, a été mis au point principalement pour le travail scientifique sur les petits bateaux.

Nuevos tipos de sondas multiples para la red

Las primeras sondas montadas en la red daban la información que se necesitaba sobre la profundidad a la que estaba el arte, su abertura, de boca el comportamiento de los peces en la boca, etc. Cuando se pescaba en aguas profundas en las que el fondo no podia localizarse fácilmente, los aparatos se dirigian hacia la superficie, pero esto creaba problemas cuando el arte se aproximaba al fondo. Entonces empezaron a montarse transductores dobles que sondeaban hacia arriba y hacia abajo; a continuación se aplicaron otros dos transductores para dar (en dirección hacia adelante), indicaciones a derecha e izquierda o verticales con objeto de dirigir mejor el arte hacia el cardumen. Las posiciones relativas del arte y el cardumen aparecen en un tubo de rayos catódicos. Más reciente es el empleo de la telemedición de la temperatura del agua. Existe otro tipo de sonda múltiple para el arte llamada "Polynetsonde" con un circuito de toma de imagen que da una presentación visual de "imagen constante". Se ha perfeccionado, principalmente para el trabajo científico a bordo de los barcos pequeños, un sistema de sonda para red con transductor múltiple, pequeño y portátil, que funciona con baterías en vez de con la corriente eléctrica del barco.

THE main problem of midwater trawling is the necessity to tow the trawl in the same depth as the fish are located. Best solution so far is the so-called netsonde.

The first netsonde had one transducer sounding from the headline downwards with a cable connection to the ship. It mainly provides the following information: distance of trawl from bottom, opening height of net, net behaviour (control of clear shooting, fouling, damage and steadiness of action), and fish distribution in and below net opening.

When sounding downwards the bottom may be outside the measuring range; the transducer can then be turned towards the surface and eventually attached to the groundrope. This was however not satisfactory since all information from below the footrope was lost. Consequently, two and more transducers were employed aiming in different directions. The first multi-netsonde equipment was developed and applied for gear development work (Schärfe, 1966 to 1969). Later on equipment for commercial trawling came on the market. All equipment discussed here has a cable connection between trawl and trawler.

NEW DEVELOPMENTS

All developments are based on the original netsonde which consists of the headline transducer mostly aiming downwards and a recording echo sounder connected by a special coaxial cable which is operated by an automatic winch. This simple netsonde is still widely used for both midwater and bottom trawling.

Very soon skippers wanted further netsonde information and so the next step was the up and down netsonde. This added two features, i.e. direct measurement of net

depth with reference to the surface and indication of fish above the headline. The only change in the layout of the netsonde was the addition of a second headline transducer and the switching device for alternative sounding with one or the other. Echo sounding and display are performed by the one existing sounder.

Due to currents, wind drift and course changes the trawl is often not accurately astern of the trawler. Since the deviation may be as much as 60° off the ship's course it might be difficult or almost impossible to manoeuvre the vessel so that the net hits the school without additional information. This can be obtained from netsonde transducers directed forward and horizontal to provide a side distinction. An additional device recently introduced is a temperature telemeter measuring the water temperature at the net. This is described in detail by v. Seydlitz (this Conference).

A multi-transducer netsonde with thermometer and eventually other measuring instruments must naturally have adequate display for conventional operation. Also, more than one sounder (and frequency) may be desirable. The present German devices use display systems consisting of recorder, cathode ray tubes (CRT) and indicating instruments.

Multi-netsonde (Elac, Kiel)

This multi-netsonde has two further transducers in addition to the up and down transducers. These two additional transducers are pointing horizontally and they are installed in the transducer board in such a way that a sonar-like "right/left indication" is obtained (fig 1). This additional information is displayed on a CRT which, in addition to the distance, also clearly shows the relative position of the net to the fish school, enabling the skipper to decide on necessary manoeuvres directly from the scope information.

Especially for estimating the amount of fish caught by the trawl the vertical sounding should not be interrupted. The continuous display of both transducer groups, vertical and horizontal, is obtained by quasi simultaneous sounding with two different frequencies.

The temperature sensor which can be added to existing netsonde equipment measures the water temperature at the net with an accuracy better than half a degree centigrade. The normal display is by a separate indicating instrument with continuous read out. For scientific purposes also recording on the echogram (vertical transducers) paper is available.

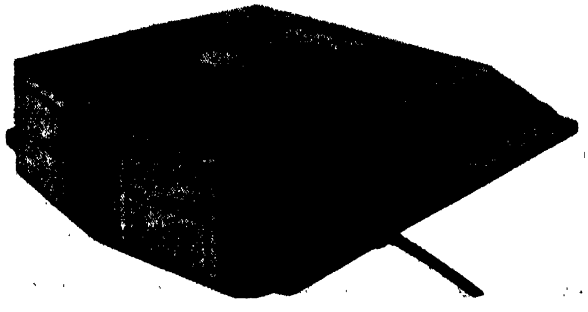

Fig 1. Transducer board of the Elac Multi-netsonde with transducers sounding upwards, downwards, and ahead from the headline

Polynetsonde (Krupp Atlas Elektronic, Bremen)

There are two types (860 and 870) which differ mainly in the sounding units employed. Both have one (down) or two (up/down) vertical transducers, the possibility of adding a "Thermosonde", can operate with up to 2,600 m cable and the basic display is recording (fig 2). For the up/down version the tow vertical transducers which are combined in one transducer board (fig 3), are

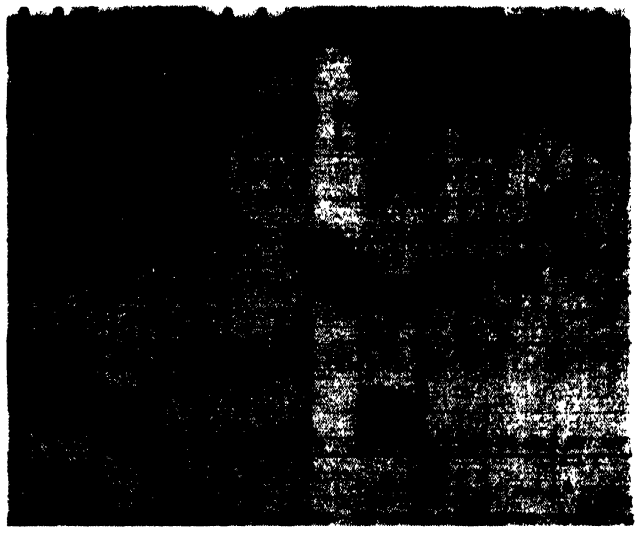

Fig 2. Echogram of the Atlas Polynetsonde with up and down transducers. 10 and 13 = distance from headline to surface: 11 and 12 = echoes of fish: 14 = groundrope

Fig 3. Transducer board of the Atlas Polynetsonde with "Thermosonde"

switched alternatively. The special feature is the availability of CRT and digital display in addition to the basic recording which improves considerably the vividness and makes the confusing change of recording ranges unnecessary.

If the netsonde must be operated on a large range in order to obtain seabed or surface recordings, the trawl opening will appear so small that an exact observation also of the fish is hardly possible. This is overcome by an additional CRT display showing the trawl opening in an enlarged scale. The type 860 has a simple device (Monoscop) with one (25 m) range. In the type 870 the CRT is a fixed part of the display unit and has three ranges (25 m, 50 m and 100 m). A video storage circuitry, which can be added, provides the additional advantage of a "steady picture".

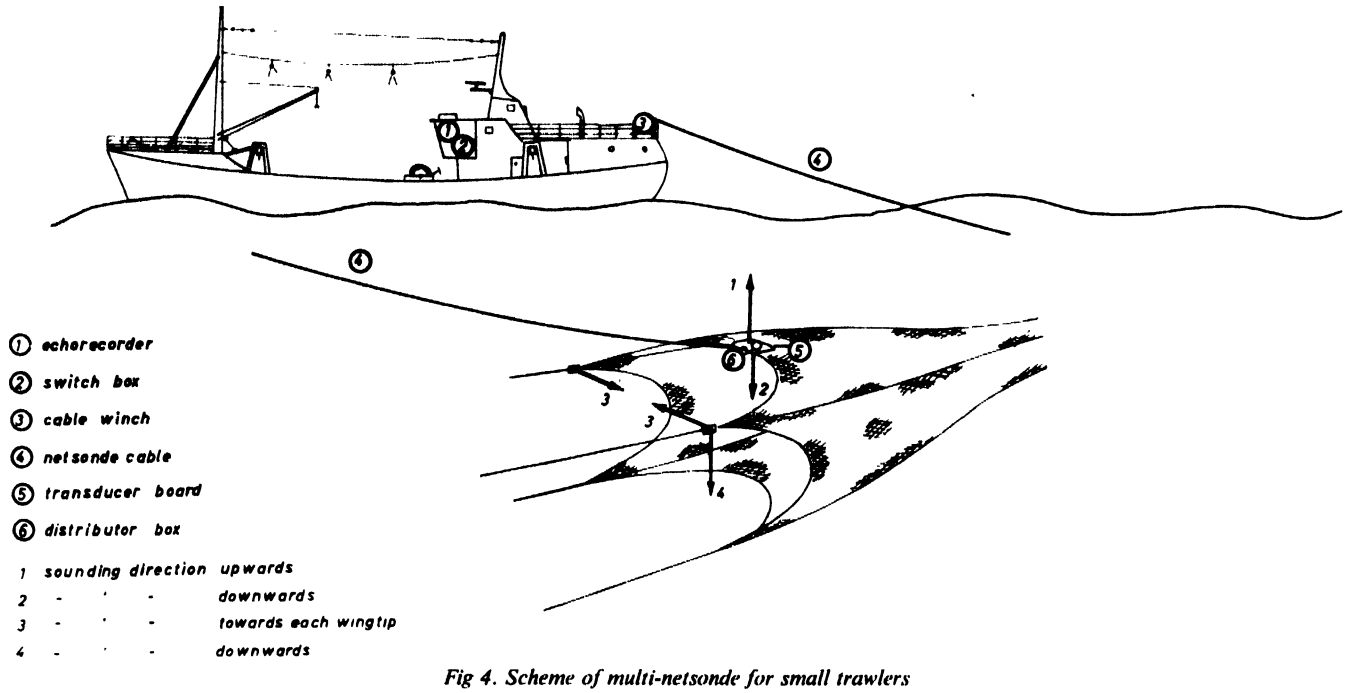

Fig 4. Scheme of multi-netsonde for small trawlers

A further sub-unit is the digital read out (Filia 520) which can be used for both netsonde types and also with the ship's sounder. By presenting both depth/height of fish and depth/height of trawl in digital form the decision making by the skipper is facilitated and miscalculations are avoided.

The "Thermosonde" is encased in a watertight ball and has an inductive connection to the netsonde transducer. The measured temperature data with an accuracy of better than 0.1°C are transmitted via the netsonde cable and recorded on the echogram as a broken line.

Multi-netsonde for small trawlers

So far, small trawlers rarely use the netsonde, partly because the normal netsonde equipment is too bulky and partly because the price is rather high and is considered to be not economical.

To take exact measurements of small boat trawls the Institute für Fangtechnik developed a small multi-netsonde which has given good results in experimental fishing (Steinberg, 1969 and 1970). It consists of echo recorder, switchbox, cable winch, netsonde cable, transducer board with pressure resistant distributor box and the different transducers (fig 4). Up to six transducers can be switched alternatively to sound from different points of the trawl.

The normal commercial echo sounder (30 kHz) needs a supply voltage of 12 V dc. The switch box on board enables the selection of the transducers via the distribution box at the net. The cable winch (fig 5) has a capacity of 500 m coaxial netsonde cable and is driven by a 2.2 kW dc iron clad electric motor (water protected) with control by a SCR-unit which allows variable speed adjustment from 0 to 78 rpm. To protect the cable, a new special cable block was developed (fig 6).

The transducer board which is made of fibreglass reinforced plastic (fig 7) is fixed in the middle of the headline in such a manner that the water flow keeps it in a stable horizontal position. Inside the board are floats which make it practically weightless in water so that influence of the board on the fishing gear is avoided.

The multi-netsonde echogram in fig 9 shows measurements from three points (1, 2, 3 in fig 4). Points 1 and 2 are the up and down transducers at the headline bosom. Point 3 indicates the two transducers, one on each tip of the upper wing legs which sound against each other to obtain an unequivocable indentification. Since the sound travels the distance only once the reading has to be doubled to get the real distance.

This multi-netsonde is easily dismountable in small parts so that it can be moved from one ship to another.

Fig 5. Cable winch with control unit

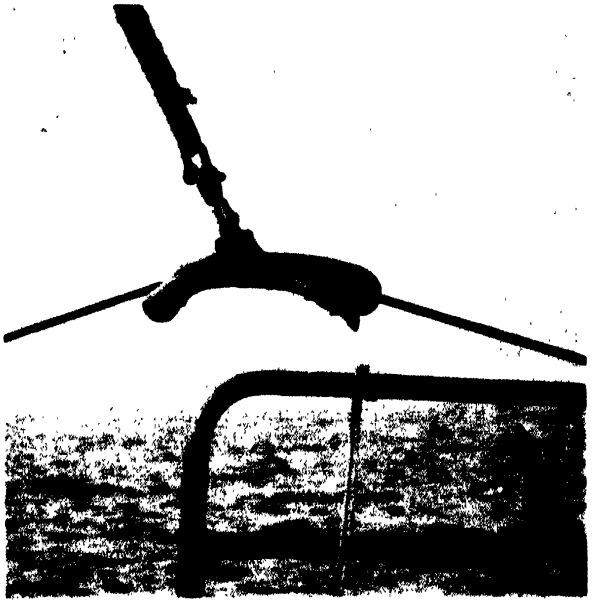

Fig 6. Special cable block

Fig 8. Transducer fixed on the upper wing for sounding downwards. The spherical float compensates the weight of the transducer in water

Fig 7. Transducer board attached at the headline bosom

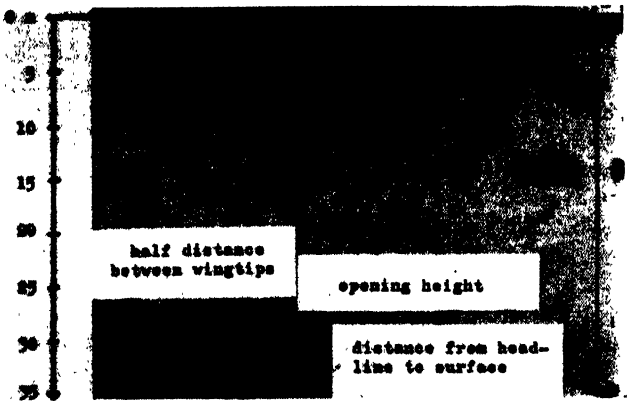

Fig 9. Echogram of the small multi-netsonde

Since most of the small trawlers do not have enough electric power supply for the winch and the echo recorder, the multi-netsonde can be operated independently from batteries and a power unit.

So far this type of multi-netsonde has been used for scientific work only. For commercial use it could be simplified.

A new multi-netsonde design (super multi-netsonde)

In midwater trawling the first step is to contact a fish school with a long range sonar. Secondly, the accurate depth of the school below the trawler has to be measured by a vertical echo sounder. With this information and the additional information of the netsonde on the depth of the trawl, the skipper is able to adjust the opening of the trawl to the same depth as the fish school.

There remains, however, one great uncertainty, namely the gap between the trawler and the trawl. The possibilities to see what happens in this area are rather poor. Often the fishing gear is not astern of the trawler due to drift by wind and current. The fish schools may also move and some show an unpredictable flight reaction from the gear and may change their position in an unexpected manner so that the trawl misses the school sideways, above or below.

Possibilities of observing the trawl in relation to the fish school by sonar ranging backwards from the trawler are limited with regard to depth (propeller wake) and distance. An obvious means for improvement is complementary netsonde sonar ranging forward, with several transducers sounding from the headline under different angles to locate the position of the fish school in front of the net.

Basic experiments with such gear were made earlier by the Institut für Fangtechnik (Schärfe, 1966; 1967; 1968).

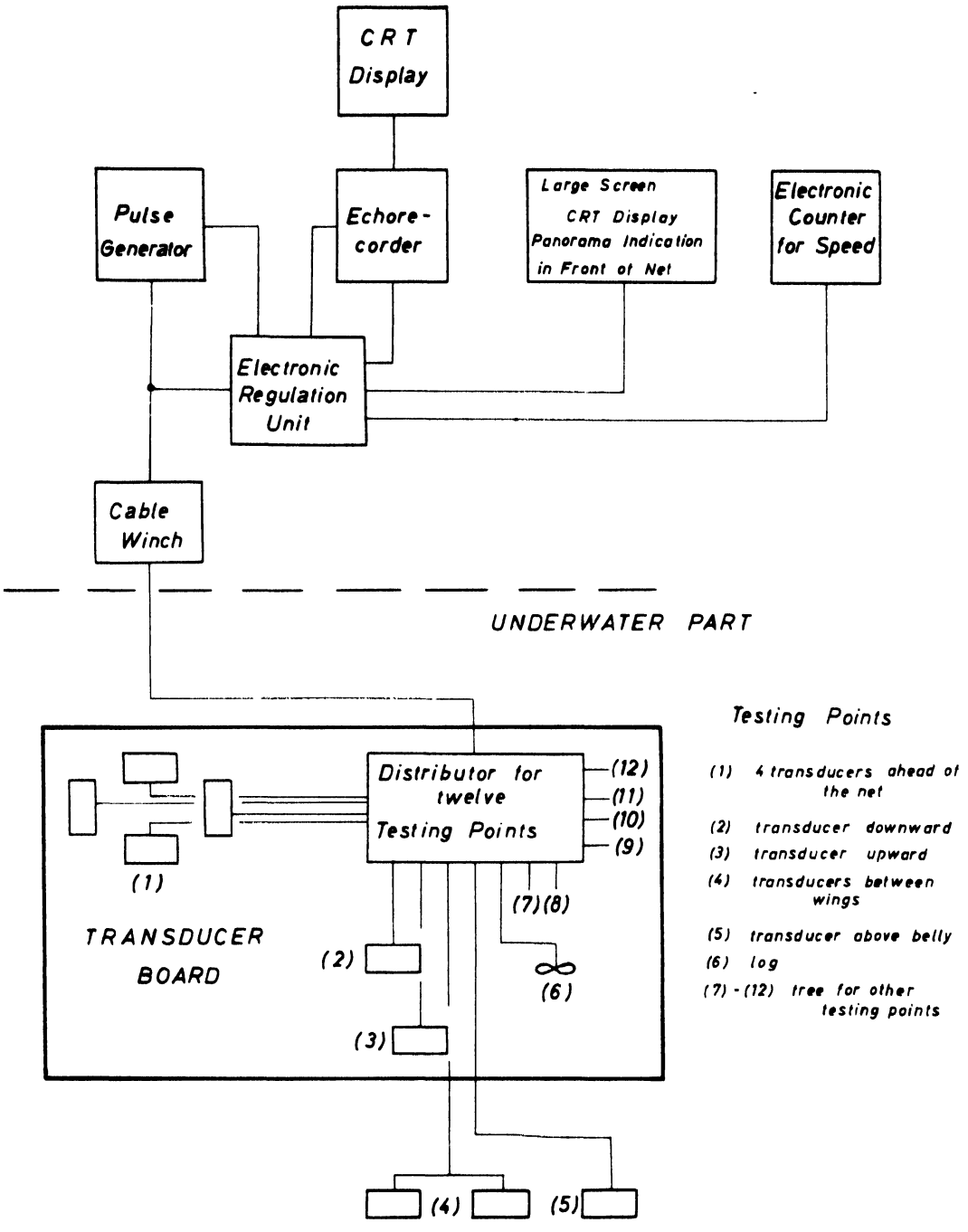

Fig 10. Block diagram of super multi-netsonde

The multi-netsonde used in these experiments had up to eight transducers, two of which were directed forward, one in horizontal direction and the other about 15° downwards. This arrangement determines the vertical position of the fish with regard to the net. The two forward transducers of the Elac multi-netsonde (2.1) are diverged horizontally against each other to determine the horizontal position of the fish.

To get the real horizontal and vertical position of the fish school ahead of the trawl these two systems were combined in the so-called "Super Multi-netsonde" (figs 10 to 12) with four forward transducers. The parametric display is made on a large screen CRT with long persistance characteristic.

Each of the four scanning beams has from the zero point in the middle of the screen an assigned direction which is comparable with the sound beam direction of the transducer (fig 11). In addition to these four transducers there are five more transducers and a net speed meter (fig 10) with another CRT display, echo recorder and an electronic counter for the net speed. The Super Multi-netsonde is an accessory unit for a normal commercial 30 kHz netsonde as is used on commercial trawlers which does not need to be specified here.

The transducer board (fig 12) is made of fibreglass reinforced plastic. Built-in floats make it nearly weightless in water. The board is fixed in the middle of the headline.

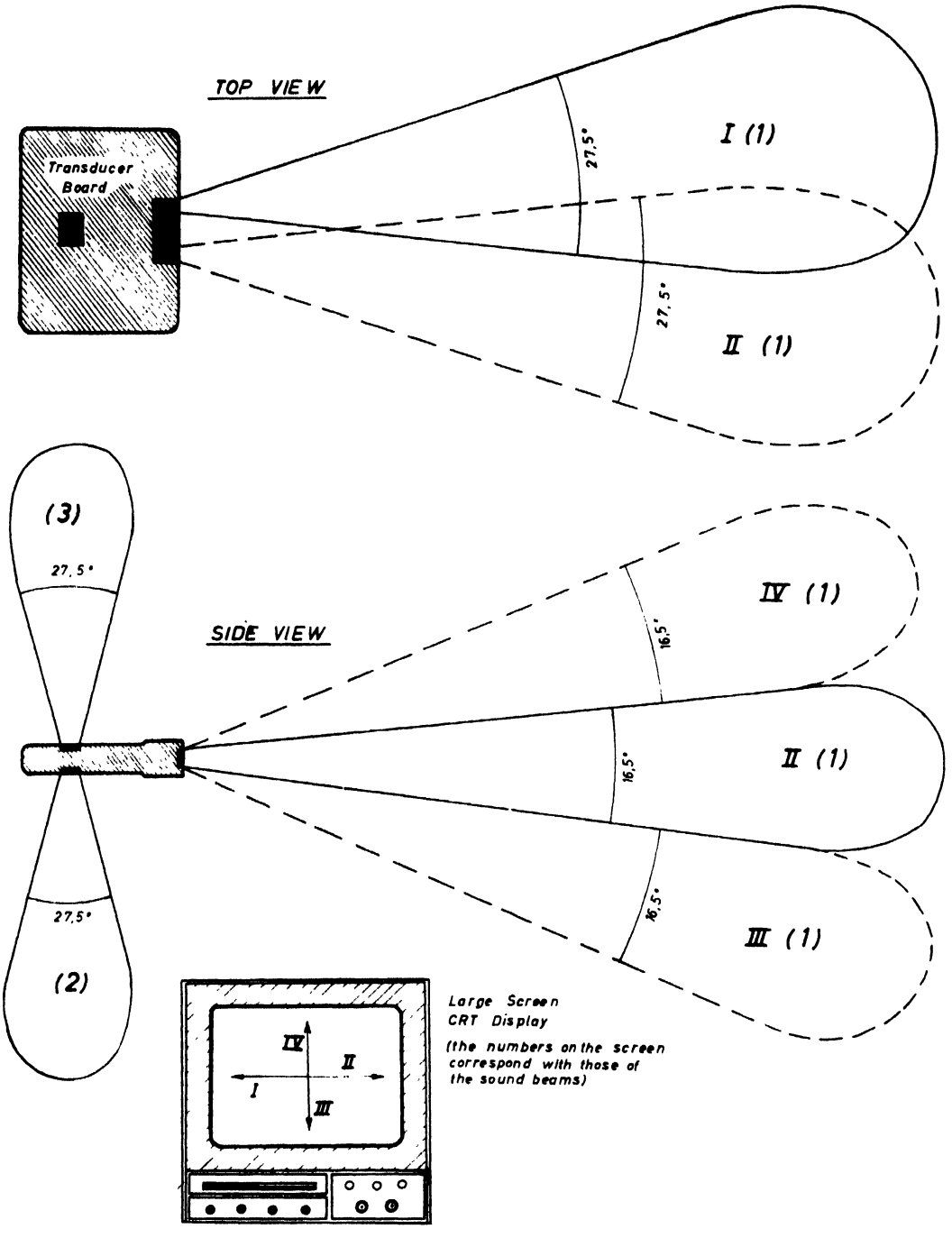

Fig 11. Scheme of the transducer board of the super multi-netsonde with beam directions of the various transducers

Fig 12. Transducer board of super multi-netsonde with 4 forward transducers

In the future this sonar feature of the multi-netsonde will become important for the development of automated trawling with electronic data processing.

Conclusions

So far the netsonde with cable transmission is the best means to get information from the trawl to the trawler. The initial difficulties with the handling and repair of the cable have been overcome. Today a really strong and well protected cable is available. With special tools and modern insulation materials the cable repair is no

problem. With the automatic winches it takes serious mistakes or very bad luck to damage this system.

The cableless netsonde systems, even with future improvements, will hardly be able to provide the same quantity and quality of information as is necessary for modern midwater trawling.

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The W.F.A. Acoustic Telemetry System

E. Allison

Le système de télémesure acoustique de W.F.A.

Le système de télémesure acoustique sans câble pour chaluts enregistre à bord pendant le trait la hauteur de la corde de dos au dessus du fond, la température de l'eau dans le chalut, la profondeur du système (chalutage pélagique) et la quantité approximative de poisson capturé dans la poche, ceci au moyen d'une transmission multiplex par 15 canaux différents. La fréquence porteuse de 55 kHz est émise au rythme de 10 à 40 impulsions par seconde en fonction des valeurs mesurées, à l'exception de la hauteur de la corde de dos qui est transmise en durée réelle. Au cours d'essais approfondis, on a obtenu un fonctionnement totalement satisfaisant des organes de mesure. On pense que la portée de transmission avec un oscillateur de réception installé sous la coque pourra s'élever jusqu'à 2000 m environ. Le système est prévu actuellement pour le chalutage de fond, mais son application au chalutage pélagique est envisagée sous réserve de modification.

El sistema de telemetría acústica de la administración del pescado de fondo

El sistema de telemetría acústica inalámbrica para redes de arrastre registra a bordo, durante el remolque, la distancia de la relinga superior al fondo, la temperatura del agua en la red, la profundidad a que está el arte (pesca al arrastre entre dos aguas) y la cantidad aproximada de peces en el copo, empleando transmisión multiplex para los diversos canales (1 segundo cada uno). La frecuencia portadora, de 55 kHz, se impulsa en proporción a los valores medidos, entre 10 y 40 impulsos por segundo, excepto en el caso de los datos relativos a la distancia de la relinga superior, que se transmiten en tiempo real. Se realizaron amplias pruebas obteniendo un rendimiento perfectamente satisfactorio con los sensores. El alcance de transmisión, con un transductor receptor instalado en el fondo del buque, se expera que llegue a 2.000 metros. En la actualidad el sistema se destina sobre todo a la pesca de arrastre en el fondo, pero con algunas modificaciones, está prevista la aplicación a la pesca al arrastre entre dos aguas.

THE lack of quantitative information about the trawl—its general condition, quantity of fish in it, ambient conditions around it—is one significant reason for fishing operations being more of an art than a science. Quite apart from the requirements of gear research scientists, fisheries development organizations and electronic firms throughout the world have been engaged in programmes aimed at measuring information at the trawl and transmitting it to the ship.

For bottom trawling in commercial conditions electrical cables or special towing warps with conductors appear to present considerable problems because of the high rate of damage which occurs on many grounds although the progress made in Germany on cable systems for pelagic trawls could well have potential in future for bottom trawling. Nevertheless, a telemetry link which does not require physical connection between trawl and ship would appear preferable and may be the only type of system generally acceptable by some sections of the commercial fishing industry.

Radio frequencies suffer severe attenuation in sea water and it is therefore necessary to consider an acoustical telemetry link, but depending upon the range, the type of information to be transmitted etc., a choice has to be made with regard to frequency of operation and type of modulation from the options available.

The White Fish Authority (W.F.A.) has been engaged in a development programme for an acoustic telemeter in conjunction with industrial firms. The objective is a commercially practicable multi-channel telemeter. It is a pulsed system designed to transmit quasi-static information at a fairly low rate.

The parameter chosen to be measured were as follows:

(a) headline height above the sea bed
(b) sea water temperature at the trawl
(c) depth of the transmitter (for eventual use with pelagic trawls)
(d) quantity of catch in codend

Item (d) is being developed separately at this writing using a single channel system and will later be incorporated in the multi-channel system. A brief technical specification of the equipment is given in Table 1.

Since all above-mentioned parameters are normally quasi-static, time division multi-plexing of the channels was considered acceptable. Each channel is transmitted for one second and a synchronizing frequency is finally transmitted for one second. To take advantage of the high power which can be transmitted efficiently by a pulse system it was decided to choose a carrier frequency of 55 kHz and to transmit the information by pulsing this carrier frequency at a rate proportional to the parameter, having arranged that the full range of each parameter could vary this pulse repetition frequency (prf) between 10 and 40 puises per second (pps). The headline height channel is now an exception to this technique which, though in the initial system was transmitted in the form of a prf is now transmitted in real time which effects a considerable simplification and readily lends itself to operating a chart display. The synchronizing prf has to be unique and is always transmitted at 60 pps.

In the shipboard display a clocking circuit steps the received pulses from one decoder/display circuit to the next, every second, and when a frequency discriminator circuit detects synchronization then the clock is restarted from zero. A synchronization lamp flashes every cycle showing that the discriminator has detected the 60 pps and, therefore, the operator can see that the system is working correctly.

TABLE 1. TELEMETRY EQUIPMENT SPECIFICATION

Transmitter
Main link frequency 55 kHz
Main link transducer beam angle 20° in azimuth, 15° vertical
Main link power 18 W in 200 μs pulses
Headline height transducer (and codend transducer) frequency 180 kHz, beam angle 40°
Power 4 W in 200 μs pulses
Batteries giving approximately 24 hours of operation/charge

Fixed hull-mounted receiver
Beam angle 29° in azimuth, 17° vertical

Shipboard display
Size 50 cm × 25 cm × 32 cm
Power supply 240 V 50 Hz
Parameters displayed on separately calibrated meters
Synchronization confirmed by indicator lamp

U.V. Chart recorder
Size approx. 40 cm × 20 cm × 50 cm
Chart type U.V. sensitive photographic paper giving instant traces
Chart speed 10 mm/min
Scale presently the chart width represents 8 metres but any scaling can be displayed simply by scanning the chart at the appropriate speed.

Transmitter construction

Design of the transmitter was based on a cylindrical housing, because of ease of manufacture, and it was aimed to keep the frontal area of this cylinder similar to that of a normal headline float. The size of the magnetostrictive transducer designed to transmit the chosen 55 kHz carrier frequency allowed the transmitter diameter to be made approximately 18 cm. The transmitting face of this transducer is inclined at 18° to the horizontal such that its main axis is aimed towards the trawler at the angle appropriate to the warp angle used by most British vessels when working in deep water.

Two versions of transmitter body were constructed. The first one was about one metre long and neutrally buoyant. The second unit was approximately 70 cm long with plug-in battery units (fig 1). The first type of transmitter presented battery charging problems since the complete unit had to be removed from the trawl in order to re-charge the nickel-cadmium batteries. The second

Fig 1. Type 2 transmitter and associated equipment

unit was a modification of the first intended as an interim measure to overcome the battery charging problem by allowing plug-in battery packs to be used. Unfortunately, the first version of this type of transmitter was somewhat too heavy (13.5 kg in water) and required a special kiting arrangement to make it stream correctly on the headline.

Both forms of the transmitter are attached to the headline by means of two shackles near the front of the unit and both units were constructed in a form to enable them to withstand the severe environment and rough handling met with on commercial trawlers.

Transducers

The height of the headline above the sea bed is measured by a pulsed echo sounder and the 180 kHz transducer for this purpose is housed in the underside of the transmitter body. The height information derived from this transducer is converted into 55 kHz pulses and transmitted to the trawler via the main acoustic link. Measurements up to 6 m can be made in the present design but this could be extended if required. The accuracy of the measurements obtained by this system is better than $\pm$ 15 cm.

Water temperature at the trawl. The transducer for this is a thermistor mounted in a plug in the main transmitter housing. Temperature can be measured in the range -1°C to $+7$°C to an accuracy of $\pm\frac{1}{4}$°C and with a response time of better than 5 s. The circuitry associated with this channel converts temperatures within the measurement range to prf's within the range of 10 to 40 pps.

Transmitter depth. This measurement was made using a potentiometric pressure transducer mounted externally on the transmitter casing and connected by a short electric cable to the transmitter. The parameter was included with a view to extending the use of the equipment to pelagic trawls. In any production equipment incorporating this parameter the sensor would be mounted within the transmitter body.

Codend quantity. There is reasonable evidence from underwater photography to assume that when fish are caught in the trawl they pack into the codend. On this assumption the U.S.S.R. for example have attempted to measure the quantity of fish caught by positioning tension switches on three cable hoops around the codend and relating this to the volume of fish caught (Hearn and Berktay, 1969).

After careful consideration it was decided to develop an alternative system which uses a small echo sounder transducer as a codend sensor. A lightweight armoured cable connects this 180 kHz transducer to the headline-mounted transmitter.

The receiving transducer

The above transducer was produced in three different forms as follows:

(a) a small unit suitable for mounting in a towed body or for sliding down a warp
(b) a hull-mounted tiltable transducer
(c) a more simple fixed-angle hull-mounted receiver.

As explained later all three types were used in trials and type (c) chosen as the most suitable for use on commercial fishing vessels.

Shipboard display

The display is housed in a small cabinet approximately 50 cm wide by 25 cm high by 32 cm deep. Calibrated moving coil meters are provided on the front panel to give a dial indication of the various parameters. It was found in practice that when poor communication was being achieved between trawl and ship these gave a badly flickering display and, particularly for the headline height, it was decided to develop a chart display. A special form of Ultra Violet recorder was developed and fig 2 shows how this operates (UK provisional patent No. 40486/69).

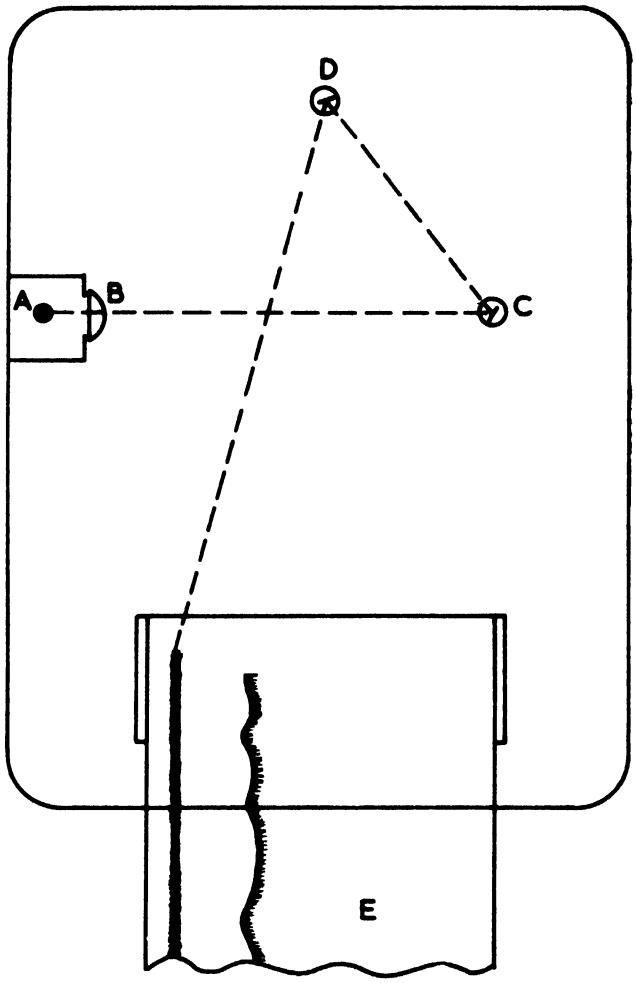

Fig 2. Triggered ultra-violet galvanometer recorder: A: U.V. lamp, B: focus lens, C: write galvanometer, D: ramp galvanometer, E: U.V. sensitive paper

EARLY OPERATIONAL EXPERIENCE

Trials were conducted on commercial trawlers mostly during normal fishing operations. Both stern and side trawlers have been used and these vessels ranged in length between 15 and 75 m.

The first trials of the warp mounted receiver were carried out on a side trawler with the main aim of

establishing an acoustic link between trawl and ship. During these experiments it was decided to slide the receiver down one of the towing warps, on a simple rubber mounted platform, so that the receiver would be far enough submerged to be below the ship's wake. A technique such as this, though not considered acceptable for commercial fishing, seemed to offer a reasonable guarantee of approximate acoustic alignment.

This system was easy to operate as far as "paying out" was concerned but great difficulty could be experienced on retrieval when the drag caused by the ship's speed could subject the cable system to considerable loads. Though the handling difficulties were in themselves somewhat discouraging for this technique, the factor which caused most concern was the very high level of noise picked up by the receiver, which was of such an amplitude that it was often larger than the signal. The cause of this interference was the vibration of the towing warps and, although different methods of decoupling the receiver from its mounting were tried, it was evident that the majority of the unwanted vibrations were water-borne and as such could only be reduced by keeping the receiver more remote from the warps.

A towed body receiver

This system was approached with a certain amount of confidence since towed bodies, in various forms, have been used in oceanology for some time. However, the particular requirement of a towed body for telemetry on commercial fishing vessels present considerable problems. They can be summarized as follows:

(a) it is most undesirable that the body should have to be taken inboard before the trawl can be hauled
(b) similarly it is undesirable that the body should have to be taken inboard during shooting or any other short inter-tow manoeuvres
(c) it is essential that the body should take the receiver below the wake of the ship
(d) it must not be possible for the body or its cable to foul the propeller under any circumstances.

To satisfy (a) and (d) simultaneously it was felt best to tow the receiver from a point about midships but to be safe and use the shortest length of receiver cable possible then its angle of entry into the water must be steep. The depth of vertical penetration below the water surface was about 6 m but the drag of the body and cable were such that it was necessary to fit a light hydrodynamic depressor to the cable, about 2 m from the body, in order to achieve a sufficiently steep angle of entry.

Though a towed body incorporating the above features performed reasonably well there were two points which were considered distinct disadvantages and detracted from this scheme being the ideal solution. These were:

(a) because of the fairly large freeboard at midships on a stern trawler it was difficult to launch and recover the body even although a boom was fitted to clear the side of the vessel and a sizeable hand operated winch for recovery
(b) at speeds higher than a few knots the towed body would skip along the surface of the water and snatching loads were transmitted along the towing cable. This caused difficulty during short periods at normal free-running speed between tows.

A hull-mounted receiver

This form of receiver completely eliminates all handling difficulties but it was also fully appreciated that there could be inherent problems which would render it of doubtful value on some vessels. The expected difficulties were as follows:

(a) flow noise
(b) hull and water-borne ship vibration
(c) propeller noise
(d) interference from ship's echo sounder.

The above points were resolved or minimized with surprising ease. Flow noise is not significant at towing speeds which are less than 5 kn. Ship vibration has not been found to be a troublesome factor except on the smallest trawler and the re-location of that transducer to an area more remote from the main engine mountings improved the receiver performance to acceptable levels. Propellers do not appear to give any trouble but care is taken to site receivers where they are wholly or mostly masked from the propeller by hull contours.

The transmission pulse of the ship's echo sounder was usually detected by the telemetry receiver but the display decoding circuits for the prf system reject this interference.

Since it is common practice to pay out warp to three times the water depth then the angle of the shortest and preferred acoustic path is approximately 18°. In order to check whether it could be advantageous to arrange that the main sensitive axis of the receiver would be less affected by propeller noise if the receiver was tilted at an angle different from 18° a tiltable hull-mounted receiver was produced for trials purposes. Signal and noise measurements were carried out over a range of tilt angles and it was found that an angle of 18° gave results which could not be improved upon by various other angles. This simple experiment inspired sufficient confidence to fit the cheaper and more simple fixed angle hull receiver of subsequent installations.

Methods of mounting the transmitter

The transmitter has been produced in two forms, the first neutrally buoyant and the second version, a modification of the first to enable batteries to be changed. This weighs about 13.5 kg in water.

This Type 1 transmitter is particularly easy to rig on the trawl. The centre of the headline is found by careful measurement and the transmitter is simply shackled to the headline at its forward end and loosely tied down to the trawl at its after end. The purpose of the loose tie is to stop the transmitter from rotating about the headline during shooting and ending up inside the trawl. The long cylindrical shape of this body is such that it streams horizontally at towing speeds and therefore an acoustic link is not difficult to establish.

Because of the shape and weight of Type 2 transmitter, tank towing tests had to be carried out to establish a suitable means of ensuring that it would stream horizontally and in a stable manner at towing speeds.

Two mounting systems were tried: (a) the transmitter was strapped to a "delta" shaped kite and manufactured in marine plywood; (b) wings were attached diametrically opposite each other on the transmitter body. The wings were of hydrofoil section and were adjustable for the experiments so that the amount of lift could be varied.

Tank tests showed that the adjustable wings were superior to the kite but the cheaper kite gave an angle of attack which deviated only slightly from the horizontal and was adequate for sea trials. It was certainly more rugged than the wings. Extra floats had to be attached to the headline in the region of the transmitter to counteract the weight of the unit in water.

Although these arrangements allow Type 2 transmitter to be used, the resultant unit is very cumbersome and will soon be replaced by another design of transmitter case which is being carefully designed for its hydrodynamic properties and which will also incorporate a convenient method of changing batteries.

RECENT SEA-GOING TRIALS

These trials have had two major objectives:

(a) to measure and record signal levels, noise levels, and interference experienced on the different ships when operated at various ranges and sea states
(b) to exercise the equipment in a normal commercial environment.

The first purpose is achieved by having first calibrated the system in a river over ranges up to 1,300 m. From this a theoretical graph of received signal against range has been produced (fig 3) and any signal measurements at sea can be compared with this prediction graph. Recorded noise levels can also be compared with this graph and the working range of the equipment in various sea stages predicted.

The second purpose is aimed at building up experience in the use of the equipment and to assess the potential of the equipment for commercial fishing operations and what modifications are necessary before the equipment is considered fully suitable for commercial use.

Acoustic link

As mentioned, the early trials were attempts to establish an acoustic link from trawl to vessel but when the receiver problems had been solved by the hull-mounted receiver system then the link performed with reliable consistency. The majority of trials have been carried out on large freezer trawlers and good links were established, with the trawl square to stern, for slant ranges of 800, 1,000 and 1,200 m. The received signal levels were such that the theoretical performance curve was confirmed.

Similarly, measurements of noise while fishing at 3½ kn show:

(a) at sea state 1 the noise level is such that the theoretical maximum range given by the prediction graph is 2,200 m.
(b) at sea state 7 the maximum range is predicted as 1,300 m.

The above range predictions assume a signal to noise ratio of 6 dB. One unsatisfactory feature of the present design is that there is a loss of acoustic signal when the trawl and the ship are out of alignment by more than 15° to 20° but the use of an array of receiving transducers should correct this possible shortcoming.

Trawl measurements

Nearly all captains with whom trials have been carried out have been impressed by the way in which the equipment, by displaying headline height, can be used to indicate the effect of small changes in trawl rigging or alterations in ship's speed. This is obviously a potentially valuable commercial tool and it is the intention to extend the range of the equipment to be able to use it on pelagic trawls when fishing them close to the bottom.

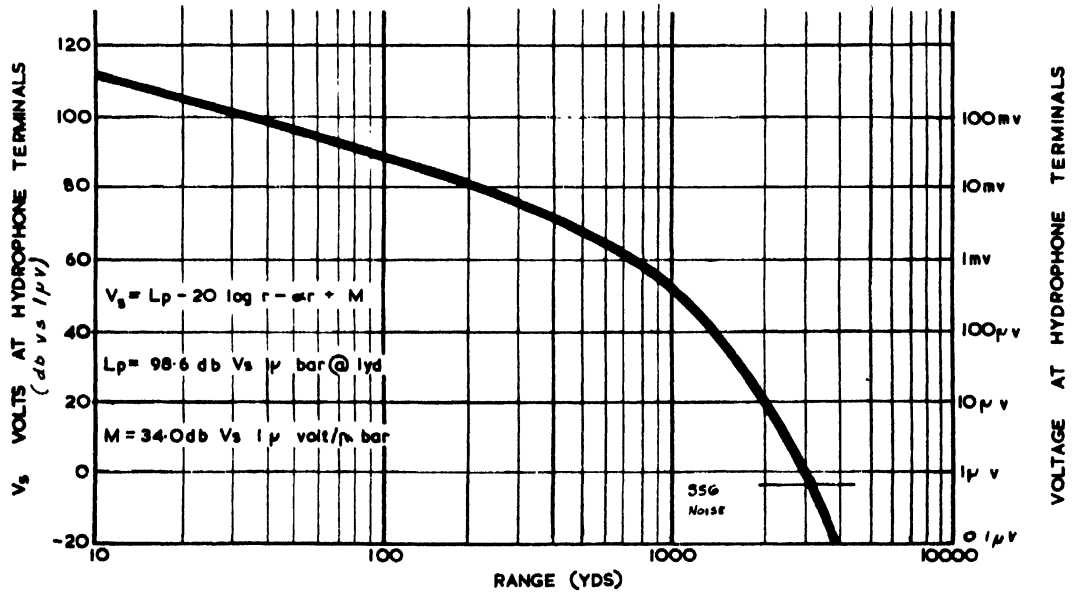

Fig 3. Signal amplitude V_s range for W.F.A. telemeter

The equipment has detected incorrectly rigged trawls (and on one occasion it was possible to indicate a parted headline due to the sudden loss of the link signal).

The temperature measurement has worked consistently well but, apart from being used as further evidence of a good link, there is still not enough statistical data available to be able to assess the commercial value of this channel.

The transmitter depth channel has consistently indicated a depth which was confirmed by the ship's echo sounder.

Although it is intended to incorporate the codend quantity measurement into the multi-channel system in the near future, the measurements so far have been made using Type 1 transmitter modified in such a way that only one continuous channel, that of the codend transducer, is in operation.

The purpose of the modification to a single channel is to enable the maximum amount of information to be obtained on this parameter during the development phase. The special form of ultra violet recorder, mentioned earlier, was the display used for this experiment.

Most sea trials for this parameter have been carried out on a 43 m long side trawler. Since an acoustic link is of prime importance, the first step was to attach the transmitter to the headline and fasten the codend transducer next to the transmitter, the coiled-up transducer cable being tied down to the headline. This approach meant that one was looking for a known measurement (headline height) which would build up confidence in the technique before moving the transducer back towards the codend.

There was no problem in using the equipment in this way, and, indeed, it is ideal for use as an "acoustic tape measure", enabling height measurements to be made at various positions around a trawl. This technique could be important in future gear development work.

The main reason for developing a remote sensor of this type was to provide the trawler captain with an indication of the quantity of fish in the codend. For this purpose the sensor was positioned on top of the net. Broadly, it was anticipated that when fish were caught, and as they packed into the codend, they would "blank off" the remote sensor. The way in which this works can be most readily explained by reference to fig 4, which is a reproduction of a chart from one particular tow in which the remote sensor was positioned at a point which, if the codend was filled with fish up to that point, it would contain about 30 baskets (about 1.1 t) of fish.

At the beginning of the tow the sensor indicates a height, above the sea bed, of about 3.0 m (10 ft). Sometimes this height indication was rather intermittent, showing that the codend was moving around quite violently, not surprisingly when one considers the construction of trawls and the nature of the sea bed. After a time, starting at the point marked "A" on the chart, echo signals start to appear, intermittently at first, at a point representing a distance of 1.3 m (4 ft) from the transducer. This distance is the minimum value which can be measured by this transducer since a "dead zone" of this amount was introduced to avoid certain acoustical problems. Signals at this distance of 1.3 m therefore indicate that the transducer is starting to be "blanked off" by fish in the codend, and, as the tow proceeds, these signals become more persistent until eight minutes after they first appear (point "B" on the chart) they become more or less continuous. At this point the gear was hauled and a catch of about 30 baskets (about 1.1 t) was obtained.

Several similar trials have now been carried out and, although the data available is still insufficient to allow detailed statistical statements to be made of the potential accuracy there is every reason to believe that a commer-

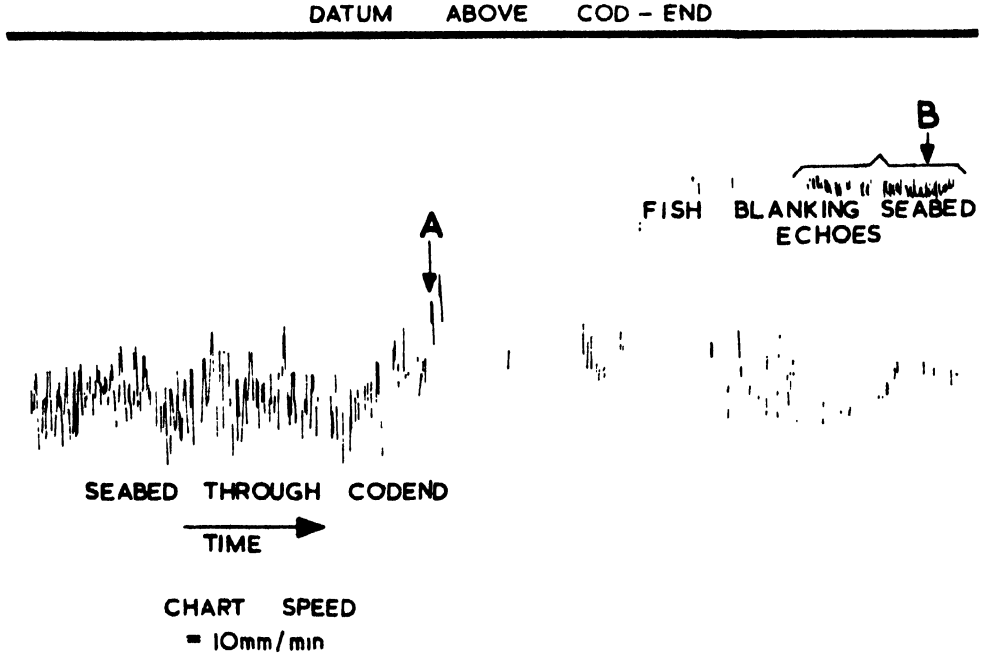

Fig 4. Chart showing codend transducer blanking with fish (vertical scale 10 mm = 0.5 m)

cially adequate system for the measurement of quantity of fish in the codend will emerge.

If it is of commercial value then it would be possible to extend the system to indicate progressive increases in the quantity of fish caught by adding more sensors. However, it is expected one or two indications will suffice for most practical purposes. One important advantage would be immediate indication that the codend has burst or been torn to the extent of losing fish.

FUTURE PLANS FOR TELEMETRY SYSTEM

Most development work here described was a co-operative venture by the White Fish Authority and the Kelvin Hughes Division of Smith's Industries Ltd. The latter are now actively engaged in designing a commercial version, with the following capabilities.

(a) parameter flexibility—the multiplexing system is such that should additional parameters be required, e.g. net mouth spread etc., then it should be possible to include this information in the main acoustic link transmission

(b) application to other types of trawling—it may be possible to utilize the equipment for use on pelagic and other trawls but this could necessitate the re-design of the link transducers to compensate for the deviation from the fixed geometry which usually exists in the case of bottom trawling.

Acknowledgement

The author acknowledges the help given by colleagues in the preparation and execution of sea trials which have made this paper possible.

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Rotor Device for Controlling Depth of Towed Fishing Trawls

K. A. Smith, H. E. Stubbs

Dispositif a rotor pour le controle de la profondeur des chaluts remorques en pêche

En chalutage pélagique il est souhaitable de pouvoir régler la profondeur du filet sans modifier la vitesse ou la longueur des funes. On considère que l'effet Magnus, qui correspond aux forces transversales considérables produites toutes les fois qu'un cylindre tournant se déplace au travers d'un fluide, peut être utilisé dans ce but. Des dispositifs à rotor expérimentaux, fonctionnant conjointement avec des panneaux, ont été employés avec succès pour modifier d'une manière significative la profondeur d'immersion d'un chalut de 40 pieds remorqué entre deux eaux. Alors que des surfaces planes ou incurvées ont un coefficient de poussée maximum (C_L) d'environ 1,5, des cylindres tournants ont fourni des valeurs supérieures à 12.

L'effet Magnus s'exprime en coefficient de poussée:

$$C_L = F_L/\tfrac{1}{2}A\rho v^2$$

où A est la surface projetée du cylindre, ρ la densité du fluide, v la vitesse de déplacement du cylindre dans le fluids, et F_L la force de poussée (le terme "pousée" est employé pour désigner les forces transversales à la direction de déplacement, par opposition à toute implication de force dirigée vers le haut).

Dispositivo giratorio para determinar la profundidad a que trabajan los artes de arrastre

Cuando se pesca entre dos aguas conviene poder regular la profundidad a que se encuentra el arte sin cambiar la velocidad del barco o la longitud de los cables de remolque. Para esto se puede recurrir al "efecto Magnus" en virtud del cual siempre que un cilindro que gira se mueve en un fluido, se crean enormes fuerzas transversales. Dieron buenos resultados los dispositivos giratorios experimentales que junto con las puertas se emplearon para alterar sensiblemente la profundidad de un arte de arrastre de 40 pies remolcado entre dos aguas. Mientras que las superficies planas o curvadas tienen un coeficiente de sustentación (C_L) máximo de cerca de 1,5, los cilindros giratorios dan índices superiores a 12.

El efecto Magnus se describe en función del C_L como sigue:

$$C_L = F_L/\tfrac{1}{2}A\rho v^2$$

en la que A es la superficie proyectada del cilindro, ρ la dens idad del fluido, v la velocidad del cilindro a través del fluido y F_L la fuerza ascensional (la palabra "ascensional" designa en este caso fuerzas transversales a la dirección del movimiento, pero nunca una fuerza ascendente).

AN early trawl designed for operation by a single fishing boat was K. H. Larsson's *Phantom Trawl*. It used the first well documented design of a hydrofoil trawl-spreader door designed to operate without bottom contact. The Larsson door is a smooth, well faired device much resembling a "stubby" aircraft wing.

Barraclough and Johnson (1956) developed a pelagic trawl using curved plywood sections to achieve the required spread for their British Columbia midwater trawl. The angle of attack of this "Dual Fin Otter Board" was controlled by vertical stabilizing fins.

The most widely used and generally accepted pelagic trawl door undoubtedly is the Süberkrüb door (Schärfe, 1964). This is essentially a curved section of steel plate, weighted on the bottom, balanced and suspended by towing warp and trawl bridles to achieve excellent horizontal spreading of the pelagic trawl.

The Cobb Pelagic Trawl Door is a streamlined wing-section door which is designed to achieve a very high lift to drag ratio. It is reported to be the most efficient pelagic trawl door from this standpoint and would perhaps be the most popular were it not for a rather complicated construction of aluminium plating and consequent relatively high cost.

While each of the pelagic trawl doors mentioned above provides "horizontal lift" or spreading of the trawl, none, with the exception of the Süberkrüb, makes any provision for vertical placement of the trawl to intercept fish schools sounded at various depths. Vertical positioning of the trawl is dependent upon a balancing of forces to be achieved by variations in towing speed and length of trawl warp. The Süberkrüb, by means of a towing point positioned above the centre of the door, provides a force for raising the door (and following trawl). An increase in vessel speed causes the door to incline "inward" imparting a vertical component to the door's thrust causing it to climb as towing at an increased speed is continued. Conversely, a decrease in speed results in a more vertical attitude of the door and this change in attitude coupled with the weight of the door permits it to settle downward. Depth positioning is dependent upon variation of towing speed.

The point of the above is to observe that each of the pelagic trawl doors developed to date is dependent upon one of two manoeuvres (or both) to achieve depth positioning of the trawl, the manoeuvres being (1) variation of speed of towing and (2) variation of trawl warp length.

Initial midwater trawling trials

Preliminary trials of the "Germans" (Schärfe, 1966) midwater trawl system in Gulf of Maine waters were made by the Gloucester EF and GR Base aboard the side trawler, *Delaware* (*I*) (Rathjen, 1961). Although limited success was obtained in taking small catches of a wide variety of fish, the larger catches (up to 4,500 pounds) were primarily herring. The gear functioned well as designed, but a need for a means to rapidly adjust the trawl depth independent of vessel speed or length of trawl warp was apparent. This need was further demonstrated when the trawl was tried on off-bottom redfish swimming at approximately 100 fm depth. Efforts to catch the redfish were unsuccessful because they could readily swim out of the trawl when the vessel speed was decreased adequately to allow the trawl to settle near the bottom.

While development of excellent improved midwater trawls was being actively pursued during the middle 1960's, there appeared to be an unfilled need for a powerful and effective means for rapid adjustment of the trawl's depth that could be effected completely independent of vessel speed and length of trawl warp. Since a midwater trawl, fishing in a particular stratum, is positioned by a rather delicate equilibrium of the forces acting upon it, it was concluded that a device or system capable of exerting a direct vertical lift (positive or negative) upon it could result in a rapid change of position to a desired depth. Such a system might greatly enhance the efficiency of pelagic trawling.

To further investigate this possibility, in 1965, the Gloucester Exploratory Fishing and Gear Research Base of the Bureau of Commercial Fisheries conducted, with Mt. Auburn Research Associates, Inc., of Cambridge, Mass., a programme of research on controllable depth trawl doors, which led to the development of a rotor door.

Development of the rotor door

The Mt. Auburn study (Fohl, 1965) initially undertook an assessment of a variety of mechanisms for implemen-

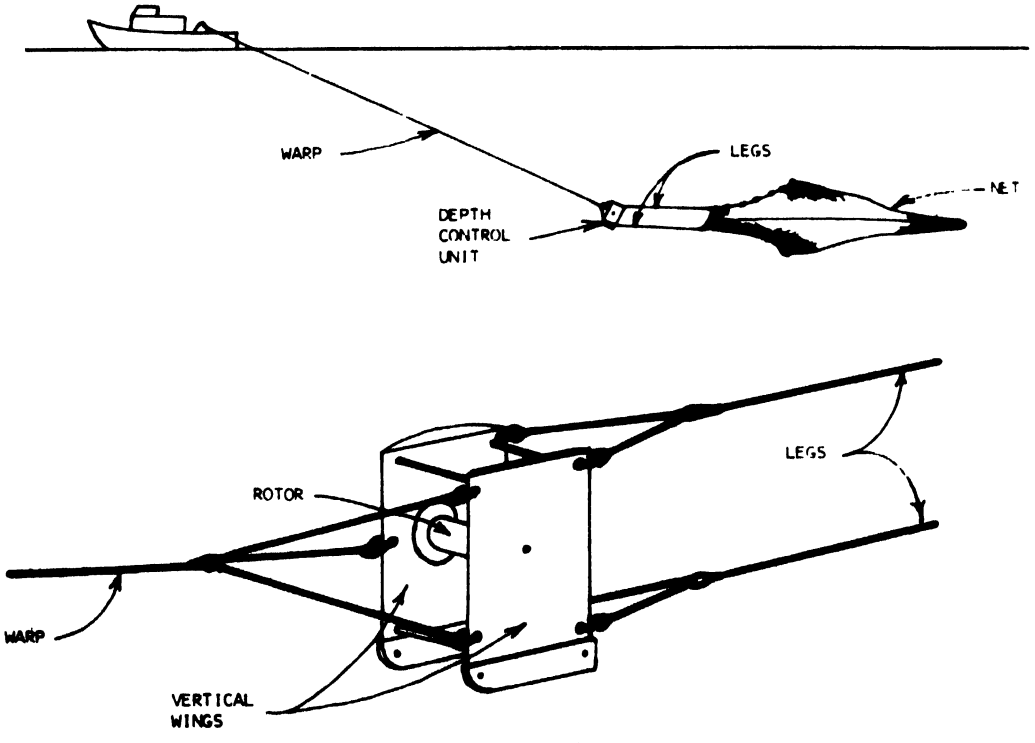

Fig 1. Rig of rotor otter board device

ting depth control, including vanes with variable angle of attack and devices with variable buoyancy. Analysis of these devices showed that they would have to be inconveniently large to develop the forces required for controlling the depth of trawls. The study also brought to light the remarkable lift characteristics of rotors which have been little used in technical applications, although they have been known for a long time. In particular, a rotor has a lift coefficient about six times as great as that of a vane. In practical terms, this means that the required forces for depth control can be achieved with a piece of apparatus of reasonable size. Furthermore, the rotor offered a simple method of control, since the vertical force is proportional to the rotation rate.

In view of apparent advantages of a rotor device in controlling depth of trawls, the programme was extended to laboratory studies and finally the construction of an operational prototype (Fohl, 1967).

The basic concept developed during this programme is to incorporate a horizontal rotor and vertical wings into an integral structural unit. Two such units are used, replacing the conventional otter boards—that is, they are placed in the rig at the junction of the warp and the net legs (fig 1). The vertical wings of each unit provide horizontal forces which hold the net open while the rotor provides a controllable vertical force used to move the net up or down. The point of application of the vertical forces is thus at the doors with the net following the doors at approximately the same depth. Each rotor is rotated by an internally mounted electric motor which can be operated at variable speed and in either direction. Variable vertical forces, either upwards or downwards, can therefore be obtained. The system includes a sounding transducer mounted on the headrope of the net (netsonde) to provide information on the depth of the net. An electric cable runs from the boat to the net to control and power the rotors and to operate the netsonde. This cable can be incorporated as a core in a warp or can be run as a separate cable. A suitable power supply and controls on the boat supply power for the rotor units.

Laboratory tests in Massachusetts Institute of Technology propeller tunnel confirmed that a rotor gave lift coefficients over 11 when operating in water. (All previous studies had been in air.) Additional tests in the M.I.T. tow tank showed that the rotor door design was generally stable.

Subsequent to the laboratory tests, two operational prototypes were built, with rotors 3 ft long and 6 in dia. The vertical wings were 3 ft high by 2 ft fore and aft. The rotors were designed to operate from 200 to 1,200 rpm.

These prototypes were tested in sea trials operating from the Bureau of Commercial Fisheries' vessel *Rorqual*. A shrimp net with a 1½ in mesh was towed. The net had a headrope 40 ft long and the legs were 30 ft long. An auxiliary electric cable was used to supply power to the doors. Figure 2 shows one of the rotor otter boards on the deck of the *Rorqual* and fig 3 shows it hanging from the gallows. The floats that show prominently in fig 2 were used in conjunction with ballast boots to maintain the door in the proper attitude.

Since no netsonde was available, the net depth was estimated from the dip angle of the warps which were short, therefore had little curvature, so that the depth could be obtained with sufficient accuracy.

Fig 2. Experimental rotor otter board on deck

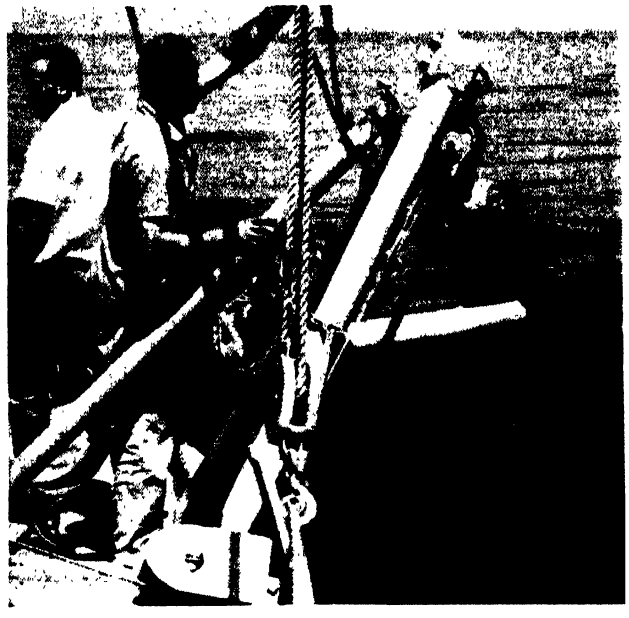

Fig 3. Experimental rotor otter board in gallows

The rotor otter boards controlled net depth with complete success. With the *Rorqual* making 3.3 kn the net could be easily raised to the surface or depressed to give a dip angle up to 31 degrees. (This would place the net at a depth slightly more than half the warp length.) The rotor otter boards could be observed from a motor launch when they were near the surface, and they rode smoothly and stably. The only difficulty experienced in

using the rotor otter boards was that handling proved somewhat awkward. In part, this was due to unfamiliarity with the gear, but it was clear that some attention should be paid to working out methods and gear for specifically handling the rotor otter boards. On the whole, however, the trials indicated that the rotor otter boards were an effective design and would fill the need for a means to adjust the depth of midwater trawls rapidly and independently of boat manoeuvres.

Alternative designs for a rotor depth controller

In addition to the design discussed above, where the rotor is incorporated into the doors, there are alternative methods for deploying the rotor. One of these of particular interest is to attach rotors directly to headline and footrope of the net (fig 4). The conventional otter boards

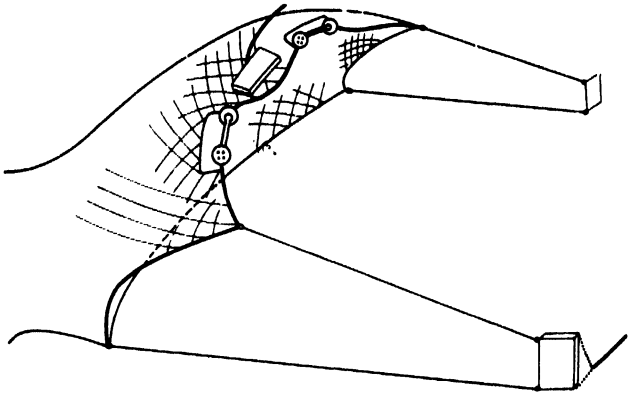

Fig 4. Proposed rotor arrangement on the headline

would be used at the front of the legs. The headline rotor would be activated to raise the net, while the footrope rotor would be used to depress the net from its equilibrium position, so that, in addition to controlling the net depth, the rotors would also open the net mouth in the vertical direction. When mounted on the headline and footrope, the rotor units would not require the vertical wings which are part of the otter board design, although end discs would still be needed to maintain the efficiency of the rotor. The resulting design would be a rather slim cylinder which might be handled more easily than the box-like design that incorporates the rotors in the otter boards.

Another alternative, applicable especially to bottom trawling, is to mount one or more rotors on the headline only. With this arrangement, the net will have a shape with a broad, low mouth, suitable for the maximum area coverage in trawling the bottom when the rotors are inactive. By applying a moderate lift to the headline through the rotors, the net will be reshaped to provide a higher mouth opening suitable for catching fish swimming a short distance above the bottom. By applying a larger lift to the headline through the rotors, the whole net can be lifted off the bottom while the otter boards continue to drag along the bottom (fig 5). With this mode of operation, the net would be in a position to catch fish swimming well above the sea floor. The use of rotors thus enables the captain to drag the bottom, and to immediately adapt his net to catch higher swimming fish

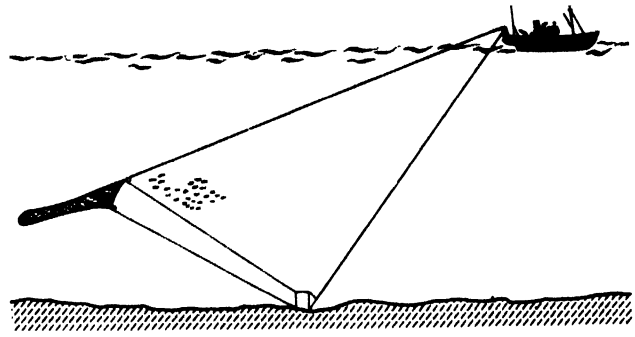

Fig 5. Proposed rotor operation on a bottom trawl for combination on- and off-bottom trawling

revealed by his fish finder. A rig of the type just described will be employed in fishing operations within the coming year in a programme sponsored by the Canadian Department of Fisheries and Forestry in collaboration with the Nova Scotia Department of Fisheries, and under the direction of W. W. Johnson (1970).

Technical basis of rotor lift

That a rotating body moving through a fluid experiences a transverse force has been known for over 100 years. The phenomenon is frequently called the "Magnus Effect" after Heinrich Magnus who first described it (1853). In this century, Anton Flettner designed and built windmills and a wind driven ship using rotating cylinders, but, on the whole, the Magnus effect has remained largely a curiosity of fluid dynamics.

The Magnus effect is an instance of the extensive modification of a flow field that can be brought about by manipulating the very thin boundary layer at the edge of the flow field.

When a rotating cylinder moves through a fluid, the boundary layer adjacent to the portion of the cylinder moving against the fluid loses energy by frictional processes, while the boundary layer on the opposite side moving with the fluid does not. The unsymmetrical energy loss in the boundary layer produces large changes in the flow of the fluid, extending to distances much larger than the thickness of the boundary layer and reaching ahead of the cylinder as well as to the sides. The result is an unsymmetrical flow with a corresponding unsymmetrical pressure distribution which is responsible for the transverse force on the cylinder.

Although boundary layer theory is useful in giving an insight into the Magnus effect, it does not provide a basis for practical calculations, and experimental investigations must be relied on for quantitative data on the phenomenon. It is convenient to describe the Magnus effect in terms of a lift coefficient

$$C_L = F_L/(\tfrac{1}{2}A\rho v^2)$$

where A is the projected area of the cylinder (i.e. length $\times$ diameter), ρ is the fluid density, v is the velocity of the cylinder through the fluid, and F_L is the lift force. (The term "lift" is used in a general sense to designate forces transverse to the velocity as distinguished from "drag" forces parallel to the velocity. "Lift" carries no necessary implication that the force is upward.) The lift coefficient C_L of a rotating cylinder is primarily a function of the

rotation ratio r, giving the rotational speed of the cylinder surface to the speed of the cylinder axis through the fluid. The lift coefficient also depends to a lesser degree on the aspect ratio (i.e. ratio of length to span) and on the way the ends of the cylinder are terminated. Figure 6 summarizes the results of Reid (1924), Ackeret (1925) and Fohl (1967). In addition, some data reported by Hoerner (1965) from an unidentified source are shown. Reid and Ackeret used air in their experiments; Fohl used water. The cylinder ends were somewhat different: Ackeret and Hoerner had rotating discs with diameters twice that of the cylinder on the cylinder ends, Reid's cylinder extended to the wind tunnel wall, and Fohl had rotating discs twice the cylinder diameter and a further extending stationary plate. All these methods appear to be fairly effective in preventing flow around the cylinder end and give sufficiently similar results to permit drawing a single curve through all the data of the different experiments. Ackeret also reports results for a rotor without end plates which are plotted in fig 6. It is apparent how severely the rotor lift is reduced without proper end terminations.

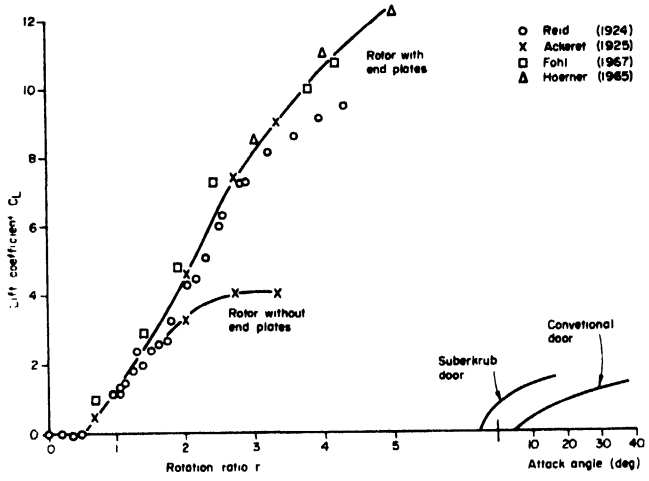

Fig 6. Comparison of coefficients of lift for rotors and otter boards

Several features of the data deserve special note. There is first of all the extraordinarily high lift coefficient realised by the rotor; the reported values exceed 12 for a rotation ratio of 5, and the trend indication is that the coefficient rises still further with faster rotation. The values of lift coefficient realized by a rotor can be compared with the maximum values of about 1.5 for flat or curved vanes. To show this comparison more vividly, the lift coefficients of Süberkrüb and "conventional" trawl doors as reported by Schärfe (1959) are shown to the same scale in fig 6. (The coefficient of the doors is plotted against angle of attack. There is of course no rotation of the doors.)

A second curious feature of the data is that the lift increases approximately lineally with rotation rate, but for rotation rates less than 0.5 no lift is generated. Reid was apparently incredulous when his measurements showed this, for he made a great many measurements (too many to plot in fig 6) with a rotation rate close to 0.5 and thoroughly verified the fact.

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DISCUSSION

INSTRUMENTATION FOR TRAWL CONTROL

Margetts (UK) Chairman: This Session will deal with present-day commercial fisheries under two sub-headings, i.e. instrumentation and trawling techniques. In the latter, bottom and midwater trawling will be dealt with together. The Rapporteur will introduce the subjects accordingly.

Schärfe (FAO) Rapporteur: As per the definition given, "aimed trawling" requires instrumentation for on time observation and measurement of the essential parameters of fish, environment and gear. The data must be presented, eventually partly evaluated, in a suitably convenient form to enable quick and efficient decision making. Means must also be available for effecting regulative action. The extent and sophistication of this instrumentation and control system actually depend on the requirements, the state of technical development, the professional skill of the operators and, last but not least, on economic considerations. Consequently there is, and always will be, quite a variety of technical levels in both commercial "aimed" trawling and in the relevant development work in different countries and fisheries. This is to such an extent that a clearcut line cannot easily be drawn between where normal or conventional trawling ends and "aimed" trawling begins. This should certainly not bother us. All trawling as all fishing and all enterprises finally "aim" at maximum yield for minimum costs anyway.

The instrumentation and control devices for "aimed" trawling are partly on board the trawler and partly on the gear. Of the on-board devices sonar and echo sounders have already been dealt with and their eminent importance for "aimed" operation with regard to fish and gear hardly needs to be stressed. Also, the normal navigational aids which are essential for manoeuvring and spot plotting have only to be mentioned briefly here. More sophisticated devices of this kind, such as electro magnetic two component log for ship's speed through water or Dobbler log for speed over ground as mentioned by **Crewe** and **Chaplin** would appear to qualify as desirable components for "aimed" trawling and should possibly be discussed, under Trends for Future Development.

Also not generally used are warp load meters as described for relative measurements with relation to speed by **Calon** and absolute measurements by **Drever** and **Lusz**. These two devices do not serve exactly the same purpose. In view of their considerable value for rational trawling some explanatory remarks from the authors would appear desirable.

The monitoring of warp angles, which is quite useful in judging certain aspects of gear performance and will probably be essential for computer automated tracking (**Crewe** and **Chaplin**), is obviously still visually carried out in commercial trawling, or by the "broomstick" technique which apparently is still considered adequate.

The first prerequisite for midwater trawling was doubtless echo sounding. The second, before sonar, and the original criterion for "aimed" trawling is the net depth telemeter. Before telemeters became available, the net depth in action was determined by depth recorders or by a second boat navigating with its echo sounder over the net. The measured values were used for compiling net depth tables on warp length, and angle or warp length and towing speed, which surprisingly are still used in some midwater trawl fisheries.

The acoustic observation of trawl gear from a second vessel was, as we have seen from **Margetts'** most impressive demonstration, recently revived in a much improved way with electronic sector scanning.

In the event of **Tucker's** expectations that the Within Pulse Electronic Sector Scanning sonar will replace the present searchlight sonars in fishing coming true, the observation of trawl dimensions, the trawl's position relative to the trawler and the distribution and behaviour of the fish in the gap between the trawler and the trawl would be improved far beyond the present state. It could, in fact, revolutionize "aimed" trawling in midwater and also on the bottom, at least under favourable conditions.

Until that happens the present searchlight sonars will have to suffice for helping to close the first part of the gap between trawler and trawl which may stretch for 1,000 m and more and is still the main problem in the "aiming" operation. Apart from seeking fish, sonar by both active ranging and passive listening to a sound beacon on the net, can serve to establish the position of the trawl gear relative to trawler and fish. There does not seem to be any reference to this important point in the presented papers and I would like to draw the attention of interested parties to my review on the German midwater trawl development published last year in *Fishing News International.*

Most of the observations and measurements of trawl gear performance and fish at the net require instruments or devices attached to the trawl and, for on time operation, also a communication link between trawl and trawler. The discussion on the comparative virtues of cable versus wireless and separate cable versus electromechanical warp is still going strong, particularly since all parties are firmly convinced they are right. **Kudryavtsev** and **Savrasov** report on investigations, trials and commercial application comprising all three types without indication of particular preferences. **Lusz** and **McNeely** are all for the electromechanical warp. In Japan the wireless acoustic link seems to have completely replaced the separate cable utilized before (**Nishimura**; **Hamuro**). Also the White Fish Authority, Hull, seems to be in favour of the wireless acoustic link (**Allison**), and **Craig** of Aberdeen, believes that in future the cable connection will be replaced by the wireless link. The German and Norwegian netsonde producers obviously have more confidence in the separate special cable, a fact supported by **Horn**, particularly with regard to the expected increase in parameters to be transmitted and orders to be returned. This is, incidentally, also my opinion.

The most important gear parameter for midwater trawling is the net depth which was determined originally by pressure telemeters, because this is simple and convenient. This principle, soon given up by some, is still utilized by the USSR (**Kudryavtsev**; **Savrasov**), Japan (**Nishimura**; **Hamuro**) and the WFA (**Allison**) all with acoustic link, and USA (**Lusz**; **McNeely**) with electro-mechanical warp. Such simple net depth meters are sufficient for particularly favourable conditions.

They are certainly unsatisfactory for more demanding fisheries where mobile and active fish and possible interference from the sea bed are involved. For these requirements the echo sounding netsonde is far superior, even in its most simple one-transducer version. The performance characteristics of this device are well enough known and need not be elaborated here. It is available with cable connection, which came first, and now also with acoustic link (**Nishimura**; **Kudryavtsev**) and is intended for inclusion, in modified form, in the WFA net telemeter (**Allison**).

To obtain netsonde sounding with one transducer in two opposite directions only the sound shielding on the reverse side of the transducer has to be removed. This makeshift down/up netsonde was utilized, when appropriate, from the very beginning and is still widely used in commercial midwater trawling. It has the disadvantages of unreliable discrimination between fish above and below the headline and of rather complicated display pattern of bottom and surface which are inconvenient to evaluate and require more than average skill if misinterpretation is to be avoided. Consequently, the two-transducer netsonde was developed for both cable and wireless and it would be interesting to hear from producers or users to what extent it is now being used.

When midwater trawling for actively-reacting fish the vertical netsonde alone is unsatisfactory because it reveals the escape of fish by diving only when it is too late to take corrective action. To close the aft part of the observation gap between trawler and trawl, which cannot be satisfactorily covered by rearward sonar ranging from the trawler, the

netsonde sonar was introduced, first on a trial base, by the Institut für Fangtechnik in Hamburg, and later by the industry. Reference is made to my review paper and to **Horn's** paper. The very similar development in the USSR (**Kudryavtsev**) could be taken as a confirmation of the soundness of this approach. In order to determine the direction of fish movements relative to the approaching trawl both vertical and horizontal fanning of the transducers was applied. I was more in favour of vertical fanning, because fish mostly try to escape downwards (see my review). In most recent developments both vertical and horizontal fanning are combined by applying four transducers (**Kudryavtsev**; **Horn**). The ideal would doubtless be the net—WPESS sonar.

These, and even more elaborate multi- or super multi-netsonde systems (my review; **Horn**; **Lusz**; **Allison**), are still under development or investigation. It would be most useful for the planning of further progress if progressive trawler skippers would say what they think about the usefulness of continuous display of information such as opening width of the trawl, horizontal distribution and movements of fish in both the net opening and further aft for improved catching efficiency.

One important parameter for which no reliable method of determination seems to have been found yet is the actual amount of catch in the codend. The technique developed in the USSR is not clear to me from the description in **Kudryavtsev's** paper and I wonder whether **Freedman** would be kind enough to give additional explanations. **Allison** attempts to measure catch volume by a longitudinal chain of echo sounder transducers on the codend which would be blanked out successively by the arriving fish. This is still under test. **Hearn's** proposal to deduce the catch amount from fish counts with the ship's sounder have already been mentioned. I myself wonder whether it would not be preferable to connect an echo counter or integrator to the netsonde transducer and would be grateful for comments from experts. At present fish traces of the netsonde seem to be the best but still unreliable means of estimating catch amounts (e.g. **Nishimura**).

From observations of interrelation between distribution of fish and water temperature comes the request for temperature-at-the-net telemeters. These are now available for commercial fishing as a component of both cable (**v. Seydlitz**) and wireless netsonde (Japan).

The actual control of the trawl gear is so far predominantly effected by course manoeuvres, towing power regulation and variation of warp length. Specific gear control devices of various kinds proposed in the past have not been accepted because the advantages were not considered adequate to compensate for the expected problems. I am glad we have at least one mention of an active net control device (**Smith** and **Stubbs**). This modern application of the Magnus effect appeals to me because, as a boy, I saw an earlier one, the Flettner rotor, on the river Elbe. Although this very efficient alternative for sails was overtaken by the more reliable propeller propulsion, the performance characteristics are such that the possibilities of applying this principle to trawl gear control might well be worth careful consideration.

So far, the complete burden of decision taking remains with the skipper who is gradually being overwhelmed by the increasing flow of incoming data on top of his numerous other responsibilities. There is also a marked variation in the capacity and performance of "human computers" which result in respective variations in catching results. Both problems could, perhaps, be solved by computer-controlled automation of suitable parts of the decision-making complex, mentioned as a rather short range aim for studies and development by **v. Brandt**, **Mohr**, **Hamuro** and for which one concrete example is described in detail by **Crewe** *et al.* This aspect is only mentioned here as an essential part of later "aimed" trawling instrument systems.

Margetts (UK) Chairman: As the first item for discussion, I propose the problem of measuring the catch in the codend during trawling.

Freedman (USSR): As trawlers do not require a high degree of accuracy in trawl filling measurements, a simplified method has been employed with three dynamometric transmitters, attached to the codend and which operate when the net is being radially extended by fish. The transmitters are connected by a special cable to the transmitting assembly mounted on the trawl headline. The signals from the trawl are received by a hydrophone which is towed behind the trawler.

Sea tests of the equipment carried out on a trawler employing midwater and bottom trawls have given positive results.

Allison (UK): Recent trials with the WFA net telemeter method described in my paper have given very promising results and will be continued.

Bennett (UK): As **Schärfe** has already pointed out there is an urgent need for the development of equipment which will simplify and improve information presented to captains of fishing vessels by their various instruments. The White Fish Authority fish counter is one such development. Its basic objective is to process the signals from the ship's vertical echo sounder in such a way as to present the skipper with a continuous reading of catch rate. The basic principle involves a continuous calibration system in which the captain injects the size of his catch into the equipment at the end of each-tow. Since the equipment has stored all echo counts during the tow it is thus capable of generating its own scaling factor for the subsequent tow. Since **Hearn's** paper was written the prototype equipment has been under continuous evaluation on commercial deep sea trawlers and is achieving the level of accuracy stated, namely $\pm$ 50 per cent for about two-thirds of the time.

Although the equipment was originally conceived as a means of assisting "average" or "below average" captains, it has been particularly gratifying to observe that even top-line men quickly appreciate the advantages of rapid and reasonably quantified interpretation of the echo sounder data.

McNeely (USA): The WFA system estimates the catch while fishing, but this one would notice anyway as soon as the trawl comes aboard. I think it would be much more valuable if one could assess the amount of fish to be caught during searching.

Bennett (UK): This would certainly be desirable, but no solution is available so far. The WFA system cannot be used for assessing the amount of fish without fishing.

Margetts (UK) Chairman: What would be the aspects of using the echo sounding netsonde for better catch estimates?

Bennett (UK): The netsonde does not cover the whole net opening. Also fish sometimes remain for some time in the opening, swimming with the net and may eventually leave it instead of going right in. These two factors would probably make the netsonde technique rather useless for this purpose.

Schärfe (FAO) Rapporteur: During years of midwater trawling trials we have repeatedly experienced fish remaining in the net opening. This situation can easily be recognized either from the netsonde echogram alone or by comparing it with the sounder's echogram so that there is no great risk of misinterpretation. Under such conditions, which are the exception rather than the rule, the netsonde is useless for estimating catches. For the majority of normal conditions I consider the netsonde indication to be basically superior to the ship's sounder indication, particularly when cathode ray

tube display is employed for the presentation of the actual echo strength. The fact that only part of the net opening is covered is no serious drawback since, with some experience, this part can be taken as a representative sample. This technique can certainly also be applied to bottom trawling. We have done this for many years and I have frequently proposed the use of netsonde in commercial bottom trawling for this purpose and also to keep better control over the performance of the gear. Some technical adaptation with regard to the width of the zero-sound and the time varied gain would be desirable for better catch estimates.

Noble (USA): I would like to mention that in the USA a net scanner is in its final tests at the moment. Its stabilized transducer system connected to the headline can scan 360 degrees in a vertical plane up, ahead, down and into the net. Presentation is on a CRT together with temperature at the net indication.

Margetts (UK) Chairman: It appears that the old problem of measuring the catch during trawling has still not been solved satisfactorily, but the attempts presently made with different systems give hope that a satisfactory solution will be found in the foreseeable future. I now propose to discuss warp load meters and I think it is true to say that these have been in use on British trawlers rather more than elsewhere and that they have been found extremely useful for purposes apart from those for which they were first envisaged.

Drever (UK): I think about 90 per cent of British deep sea trawlers carry warpload meters and it is common practice to adjust revolutions of the engine to agree with the desired towing power shown on the warpload meters. In the old days it was thought that only 5 to 10 per cent correction in throttle was needed to overcome effects of tides, currents and wind. However, since we have had warpload meters it has been shown that 20 to 50 per cent correction in throttle may sometimes be needed. They will also give indication of damage to the net, but this of course can only work in good weather as fluctuation of warpload in heavy seas makes this undetectable. A paper recorder would be highly desirable to determine the difference in the first and last parts of each tow. In this way we can better detect gear damage. Some people suggest that the additional sheave causes wear on the warp but I feel the benefits far outweigh the minor wear that may occur.

Portier (France): French trawlers also use warpload meters and skippers realize their value particularly on deep sea trawlers. An indicator alone is considered insufficient and an additional recorder is needed. This equipment is also useful in pelagic trawling. All trawlers should be equipped with warpload meters. There are two types on French trawlers, one with a load cell and one in combination with the winch. Both types give good results.

Schärfe (FAO) Rapporteur: The French warpload meter mentioned by **Calon** is combined with towing speed recording. I believe this is the same type as was originally developed by **Hoppe** in Germany and was claimed also to be useful as a catch indicator.

Drever (UK): We have tried to use the warpload meters to determine catch rates of fish and our experience has been that this is impossible.

McNeely (USA): For a number of years we have employed warpload meters on our research vessel and have found no indication at all as to catch of fish. This is to be expected since the tension on the warp is determined by the setting of the throttle without regard to how much fish is in the net.

Schärfe (FAO) Rapporteur: **McNeely** is quite right in stating that the warpload alone cannot be taken as a measure of changes in gear resistance which may be due to catches. For this the towing speed must also be taken into consideration as is the case with the **Hoppe** system I have just mentioned.

Muschkeit (Germany): The warp load meters on many German trawlers have pressure sensors located on the brakes of the trawl winch and recording display so that one can watch recordings of a tow and see when gear damage occurs. It is not so easy to recognize net damage but if the gear comes fast one can detect it and take immediate action. If a large rock is hit which could perhaps damage the net this will be shown and one can haul up the gear to avoid non-productive towing.

Gronningsaeter (Norway): Warpload meters combined with the winch brakes are not sensitive enough. The system of using deflection of the towing warp is much better. I have seen a trawl hooked up and the strain taken by one warp only without a clear indication of this by the winch-mounted system.

Besancon (Netherlands): On the Dutch research vessel *Tridens* warpload meters recording the tension on each warp separately are always used, also to determine towing resistance of experimental trawls. During research on trawls with larger meshes in the forward part of the net the change in towing resistance could be determined in absolute values.

Gorman (Australia): We would like to get warpload meters on the new Australian research vessel (80 ft, 500 to 600 hp) but could not find suitable equipment on the market. Units for large European trawlers are too big and too expensive. Where could adequate devices be obtained?

Bennett (UK): In the UK a range of warpload meters is available for all sizes of vessels down to 50 ft length adopted for both side and stern trawlers. Advice is available from the Industrial Development Unit of the WFA in Hull.

Margetts (UK) Chairman: It was suggested that sector scanning sonar might replace the presently more common searchlight sonar. In my opinion these two sonar systems are complementary and in combination can be a very powerful tool indeed, at present for research and in the future, hopefully, also for fisheries.

Mitson (UK): There are basically two within pulse sector scanning sonar (WPSS) systems available, the delay line scanning system and the modulation system, the latter having definite advantages. There is no doubt that such a scanner unit could be made and fitted to the headline but the range would probably be limited to about 50–70 metres. A high quality cable link would be a necessity.

Margetts (UK) Chairman: For instrumented aimed trawling the communication between trawler and trawl is of vital importance. It would therefore appear useful to try to evaluate the pros and cons of the different system for different conditions and purposes.

Miers (Germany): The following points indicate the limitations of acoustic (wireless) links:

(1) Under favourable water conditions with scattering layers, e.g. cold water on top of warmer water—which are often found—the link will tend to break due to sound deflection. (2) Fishing grounds are usually packed with trawlers. If they all operate wireless acoustic links interference is bound to become a problem. (3) The continuously increasing demand for more information from the trawl will soon make the

wireless link technically uneconomical and its usefulness will end as soon as orders have to be transmitted back from the ship to the trawl.

Boonstra (Netherlands): Trials in Holland have given good results with the Japanese wireless netsonde. Even with scattering layers, present working ranges of up to about 600 fathoms were obtained. With the transmitter mounted on the otter board the spread or depth of the otter board could be measured. Nevertheless the cable link will ultimately be the more reliable solution.

Nomura (Japan): In Japan the wireless acoustic link is used on big and medium sized trawlers with very good results. The system could also be used for purse seining.

Suarez Llanos (Spain): The majority of Spanish trawlers fishing off South Africa, i.e. more than 50 vessels, use the wireless Japanese netsonde with good success on bottom trawls. This system has an additional advantage. In the event of the warps breaking valuable trawl gear can easily be located and retrieved because the acoustic netsonde signals continue for about 24 hours until the batteries are exhausted.

McNeely (USA): Concentrations of fish are often a result of dissimilar water masses which make for poor transmission of sound due to deflection. It does not seem logical to have a piece of equipment so vital to the fishing operation because there will be times when it will not work, particularly in areas where one expects to find the greatest fish concentrations. Off the West Coast of the United States we have the mighty Columbia river which creates such dissimilar water mass conditions and in this area I have attempted to use several commercial models of acoustic telemeters and in addition some experimental acoustic devices and on many occasions was unable to receive a signal.

Craig (UK): There are two sides to the argument. The wireless link is a significant development, but it has power limitations. For trawl gear research by the Aberdeen Marine Laboratory we are using two communication systems. From the trawlnet itself we use a 16-channel amplitude modulated acoustic link and from the otter boards communication is by wire conductor in the trawl warps. The advantages of the latter increased with greater distances.

Mitson (UK): As regards maintenance and repair, the wire system with separate cable needs little skill (as is available on trawlers) while the acoustic (wireless) system needs great skill.

Mross (Germany): Warps with internal conductors work very well until damage occurs, which is difficult to locate and very difficult to repair. Therefore "electrified" warps can hardly be recommended for commercial trawling. With regard to the complications mentioned in **Craig's** paper I would say that for bigger trawlers the complications associated with the wireless equipment exceed those of the separate cable link. It may also lead us to think that our Norwegian friends, who several years ago were supposed to be "just around the corner" with a wireless system, finally and recently introduced the cable system. According to our experience trawler skippers, once accustomed to a good cable netsonde, want to have more and more information on what is happening in and around the gear. Technically that means that we have to switch from thinking in terms of single equipment to thinking in instrument systems, to meet the trend towards integrated trawl information systems. I believe that such systems will have to rely on a cable as a stable and efficient information link. This applies mainly to the bigger trawlers. For smaller boats, where difficulties with the acoustic link are quantitatively smaller, the wireless system with its lower price might be useful.

Knudsen (Norway): It is true that a few years ago we were optimistic about the wireless netsonde but meantime trawling has extended to greater depths so that it is not only the distance to the trawl which has to be considered, but also the difficulties with temperature layers in the increasing depths where trawling today often takes place.

Di Mento (Italy): The attempts to evaluate different communication systems by our Institute in Ancona which are not concluded yet, suggest that each has merits for specific purposes. For midwater trawling the separate cable presents no problems in operation and therefore is probably best. For bottom trawling the separate cable is expected to give operational trouble (bottom contact, fouling, etc.) particularly with the typical Mediterranean bottom trawl which has only about 1 m opening height. For this, the acoustic link may be preferable. Since a cable connection between the otter boards and a central communication unit on the net is very inconvenient, observations and measurements at the otter boards are probably best transmitted through a special warp as described by **Craig**.

Schärfe (FAO) Rapporteur: Separate cable connections to bottom trawls can and are being used also in commercial trawling without difficulties. The coaxial cable with tough plastic insulation, outer diameter about 12 mm, breaking strength about 1.5 ton, now common for netsonde, does not sag down but is curved upwards at towing speeds above 3 kn. At lower speeds the 50 m next to the net can be lifted by a few floats. During electrical trawling trials two cables, i.e. the heavy cable for electric supply to the net and the netsonde cable, have been used side by side without any entanglement or other difficulties.

Proctor (Canada): Trawl observation seems to be centred on net sounders either cable or acoustically linked, each with its individual problems. A further means is the high speed scanning sonar which can view the net from the trawler and, if necessary, use a vertical scan in the stern view to obtain net depth. This is one of the reasons why in Canada the high speed 360° scanner is supported for use in midwater trawling without the liabilities of net sounders.

Schärfe (FAO) Rapporteur: This application of high speed scanning sonar would probably be impeded by limited working range and falsifying influence of water stratification.

Margetts (UK) Chairman: It appears that all trawl-trawler communication systems tested so far, i.e. special warp with inside conductors, separate cable and acoustic link, have advantages and drawbacks and will for some time to come continue to be used side by side according to conditions and requirements. Since the depth control of midwater trawls is of vital importance the opinion of skippers and gear technologists on the feasibility and possible advantages of the rotating shearing device as compared with the so-far standard technique of warp length and towing power variation should be of considerable interest.

Stubbs (USA): I am convinced that the increased freedom of manoeuvre given by the Magnus system proposed in my paper is worth having. Rather than manoeuvring the net through a long cable it is better to influence the system at the net or at the otter boards. Other applications are possible such as vertical rotors to give lateral control of the net.

Schärfe (FAO) Rapporteur: Skippers will probably have strong reservations because of the complexity and the consequent sensitivity of the rotor device to mechanical damage.

On the other hand this powerful and easily controllable shearing system offers a number of new possibilities of which the speedier lifting of midwater trawls is only one. It should therefore be considered carefully whether it would not warrant strong efforts to overcome these problems which, in addition to rugged construction, would probably have to include changes to the trawl gallows and the handling pattern.

Mross (Germany): The practical appliction of this system will also depend on finding a reliable solution for the power supply to the rotors. This would probably have to be by a coaxial cable because a multi-core cable is bound to cause difficulties.

Stubbs (USA): The power requirements depend on the towing speed and on the size of the net system. There is an application being considered for Canadian fishing where the rotors are 6 ft long and 1 ft in diameter with the rotors mounted on the net rather than at the doors. This system will require 2 hp on each rotor.

Margetts (UK) Chairman: Of the subjects raised by the Rapporteur only one more can be discussed and I invite information and comments on the extent of practical application and experience obtained so far of temperature-at-the-net telemetry.

Keirat (Germany): I consider that the measurement of water temperature at the net has important applications in trawling. Several trawlers of our company have started to use the new devices at Greenland and on Georges Bank but it is still too early for decisive results which we expect to be favourable.

Mross (Germany): Experiences with the temperature telemeter are by no means complete yet. So far there has been some success during pelagic trawling for cod, but for other species it is too early to say.

Miers (Germany): We have not had much experience yet in this field but I am able to say that it has found its uses in herring trawling when the herring is spread out. One skipper towed out of an area of good fishing, noticed that the temperature had changed and returned to the area where the herring were.

Taillliez (France) (written contribution): Several manufacturers have recently introduced temperature recording equipment of sufficient accuracy (about $\pm$ 0.2°C) in conjunction with the netsonde. This is a significant development because it will lead to the generalization of a technique—fishing with a thermometer—which until now has been little used by commercial trawlers.

There are many instances where the water temperature has an important influence on fish distribution in time and space. For instance, species which are particularly sensitive to temperature (stenotherm) such as Clupeoids and tuna will keep inside preferential temperature zones; in geographic regions with very strong thermal characteristics (e.g. Newfoundland, North Sea in summer) fish often concentrate close to the thermal borders in search of food, for spawning, or other purposes.

The handling of the combined netsonde—thermometer in trawling is the same as for the conventional netsonde and it will take the skipper only a short time to become familiar with the temperature reading. By taking into account the time of the year, the place, the species sought, etc., he will classify and log all valuable information and thus by comparing his findings, from one year to the next, accumulate experience for more efficient fish location. A preliminary knowledge of the oceanographic conditions on the fishing ground may sometimes be advantageous and this could be achieved by a rapid survey in which the temperature-netsonde is towed without the trawl by using a special stabilized diving device. Also in fisheries other than trawling, for instance tuna fishing, the latter method would be of special interest for fleet searching vessels looking for oceanographic fronts, either on the surface or in depth.

The combination netsonde-thermometer might also facilitate oceanographic surveys of research vessels. Conventional methods generally imply stationary observations which are sporadic. A temperature-netsonde device installed in a towed diving body, the depth of which could easily be modified while steaming, would make possible continuous "Sinusoidal" oceanographic surveys. The direct relation of temperature to depth will greatly facilitate interpretation of the data. The advantages would be quicker and easier assessment of quite a number of oceanographic phenomena such as hydrological fronts, vertical or horizontal temperature gradients; location of thermoclines and also routine oceanographical sections and mapping.

Aimed Bottom and Midwater Trawling Techniques of Japanese Factory Sterntrawlers

K. Kodera

Techniques de chalutage demersal et pelagique controle employees par les chalutiers usines a pêche arriere japonais

De 1911 à 1956, la Nippon Suisan Kaisha, Limited a effectué des opérations de chalutage qui ont couvert la Mer de Chine orientale, principal lieu de pêche, et les secteurs de la Mer de Chine méridionale et de la Mer de Bering. Ces opérations s'étendent aujourd'hui à presque toutes les parties du monde, y compris l'Atlantique nord-est, sud-est et nord ouest, ainsi que le Pacifique nord et sud-est. Jusqu'aux environs de 1956 les types de chaluts utilisés ont été le filet à deux faces pour le chalutage avec des panneaux et le filet à quatre faces pour le chalutage à boeufs. A la suite de l'introduction du chalutage par l'arrière, en 1960, un filet amélioré à 6 faces, dérivé du filet à quatre faces, a été mis au point puis utilisé dans la pratique, en même temps que des panneaux hydrodynamiques. Des aides électriques à la pêche, comme le netsonde sans câble et l'écho-sondeur multistyle, sont entrées aussi en usage dans le chalutage sur le fond, à une certaine distance du fond ou entre deux eaux. On a mis au point également un chalut combiné pour la pêche au fond ou pélagique. La contribution présente les vues de la compagnie sur la mise en pratique et l'amélioration des techniques et des engins de pêche, en faisant brièvement état, en conclusion, du résultat obtenu par l'armement dans le chalutage pélagique contrôlé du hareng en Ner de Béring.

Tecnicas de pesca dirigida al arrastre en el fondo y entre dos aguas, aplicadas por arrastreros factoria Japoneses que pescan por la popa

La Compañia Nippon Suisan Kaisha, Limited ha llevado a cabo operaciones de pesca al arrastre desde 1911, abarcando hasta 1956 el Mar de la China Oriental, que fue el principal caladero, y el Mar de la China Meridional y las zonas del Mar de Bering. En la actualidad, las operaciones se extienden a casi todas las partes del mundo, incluyendo el Atlántico nororiental, sudoriental y noroccidental, así como el Pacifico septentrional y sudoriental. Los tipos de redes de arrastre usados hasta 1956 aproximadamente, fueron la red de dos paños para la pesca con arrastre de puertas y la de cuatro paños para la pesca al arrastre en parejas. Después de la introducción de arrastreros que pescan por la popa en 1960, se construyó una red perfeccionata de seis paños basada esencialmente en la de cuatro paños, y empezó a usarse junto con puertas de arrastre hidrodinámicas. Se han usado también en la pesca al arrastre, fuern del fondo y entre dos aguas, instrumentos pesqueros de tipo eléctrico tales como la "netzsonda" inalómbrica y la ecosonda de aguja múltiple. También se ha creado una combinación de red de arrastre de fondo y entre dos aguas. Expone el estudio la opinión de la compañía sobre el desarrollo y perfeccionamiento de los artes y técnicas pesqueros y concluye la presentación con una breve referencia a la actuación en la práctica de la pesca del arenque al arrastre que la compañía efectúa entre dos aguas en el Mar de Bering.

NIPPON Suisan Kaisha Limited has been engaged in trawling operations since 1911. Until about 1956 these operations were conducted chiefly in the East China Sea, with some activity in the South China Sea and Bering Sea areas. Following the introduction of stern trawlers in 1960, trawling activity was progressively expanded to practically all parts of the world, including the northeast, northwest and southeast Atlantic and north and southeast Pacific. The present fleet consists of 20 large trawlers of 2,500 GT and above, totalling approximately 60,000 GT, and more than 70 small trawlers and two-boat trawlers.

The companies goal with respect to trawl gear and techniques has been to rectify the thinking which still prevails that different fishing gear and fishing techniques must be employed for bottom trawling, off-bottom trawling, and midwater trawling, and to develop a gear and technique that would enable using a common trawl net with equal effectiveness for all three conditions.

Already some species such as Pacific ocean perch (*Sebastodes alutus*), Alaskan pollack (*Thergra chalcogramma*), cod, and boar fish (*Pseudopentaceros richardoni*) are being efficiently caught on the continental shelf both in bottom and midwater trawling with a common trawl gear, although there is still much room for improvement as regards gear structure and electronic fishing aids. Such versatility owes much to fishing aids such as the fish finder, sonar, cable-less netsonde, loran and automatic course recorder, so much so that present-day trawling techniques may well be dubbed "instrument fishing".

However, it is only when increased vessel efficiency, improved gear design and advanced electronic fishing aids are wedded with the superior fishing techniques of the skippers and crews who operate them that modern fishing can succeed.

As a problem for future research, it is important that improvements be made in gear structure and fishing techniques which could effectively cope with the behaviour of the various fish species. In working towards this end, the gear should be so designed that it could catch as many different kinds of fish as possible, whether they be on the bottom or off the bottom. Such a gear would eliminate loss of time in changing from one kind of trawl to another, and enable economizing on gear cost.

Viewpoint on trawl gear

Up until about 1956 when trawling was mainly in the East China Sea, our trawlnets were of the two-panel type (upper and lower panels), while for two-boat trawling the four-panel type was used. These were towed at speeds of about 2.0 to 2.5 kn. As fish finders had not yet come into general use, neither the depth of the fish schools nor their vertical distribution could be determined. Our goal on gear improvement was still undefined at the time. For these reasons, we were always left in doubt as to what the height of the net opening should be, whether it would be advisable to increase the towing speed, and where to strike a happy balance between these two conflicting factors. The improvement and adjustment of the trawl gear was governed by experience derived from trial and error.

With the appearance of the fish finder echo sounder, followed by the advent of the cable netsonde, it became possible to determine concretely the height and width of the net opening and the required towing speed. Parallel

with the application of these new equipments, model tests in running water tanks were employed to further clarify the actions of the net and auxiliary gear.

The following will give a rough idea of the degree of technical development which we have been able to attain to date:

(i) When towed at a speed of 4.0 to 4.5 kn by a 3,900 hp, 3,500-ton class stern trawler:

In bottom trawling:

Height of net opening	10 m (33 ft)
Width between wingtips	28 m (92 ft)

In midwater trawling:

Height of net opening	20 m (66 ft)
Width between wing tips	25 m (82 ft)

(ii) In midwater trawling the net depth is adjusted with the warp length and fine adjustment with the revolutions of the main engine. Due to limitations of the cableless netsonde, the actual range over which the net can be accurately aimed on fish schools is between 0 and 400 m (220 fm) off the bottom.

(iii) As regards the net, the number of component panels has increased for both bottom and midwater trawls, and by means of dispersing the towing tension with rib lines an effective lifting and gravitating action has been sought. As a result, an adequate opening of the net is obtainable even at high towing speeds, with the opening forming a favourable oval and the overall net also filling out favourably, thus avoiding wrinkling caused by excess netting.

TRAWLNET TYPES

Prior to around 1956 our 300- to 500-ton class side trawlers with around 750 hp fished exclusively with two-panel trawl nets (fig 1) and were only able to maintain an opening of 1.5 to 2.0 m (5.0 to 6.6 ft) in height at a towing speed of 2.5 kn.

Later, with the advent of the large stern trawlers (2,500 to 4,000 GT), our operations were extended to increasingly distant waters and involved an increasingly larger number of species of fish, with the result that far more exacting sets of requirements were demanded of the trawl gear in respect of towing speed, strength of netting, net opening, etc. These demands have more or less been met through model testing, coupled with improved quality of materials for netting and auxiliary gear and advances made in electronic fishing aid equipment.

Two-panel bottom trawlnet

Figure 1 is an old type two-panel bottom trawlnet shown in sideview (i) and plane view (ii) under tow, and (iii) as construction plan.

This two-panel net fills out well under tow and generally shows very little distortion. However, although the headline should be relatively longer than the footrope, in actual use the opposite is the case. The reason for this is that if the footrope is shortened in relation to the headline, the rib line (A′, A″) will become taut and cause point A′ of the footrope to rise, resulting in a poor bottom contact. On the other hand, if the headline is shortened, tension on the headline increases in relation to the tension of the footrope and this results in a poor net opening.

Improved two-panel bottom trawlnet

To improve the net opening, the old type net (fig 1) was modified by adding an extra triangular netting wedge CBE (fig 2, (i) and (ii)).

As most of the resistance of the trawl net will fall on the rib line (CB′E) and footrope (DB″ A′), point B of CBE is loose and can lift up for improved opening height. However, point E tends to be pulled downward by the

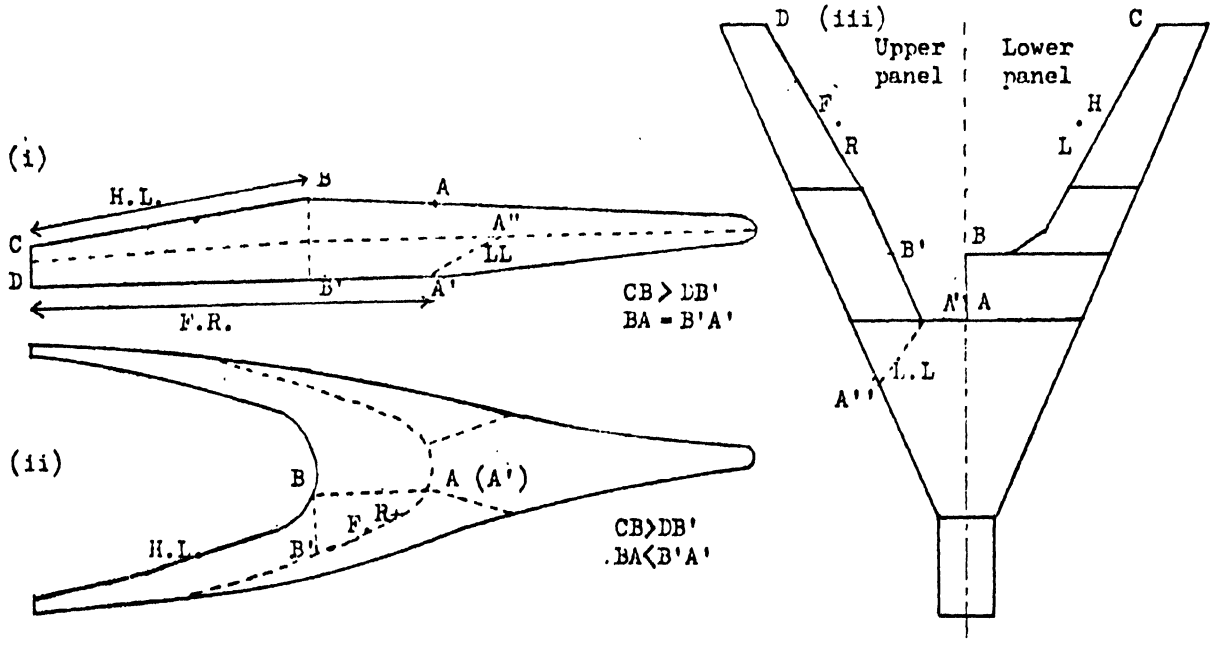


Fig 1. Two-panel trawlnet

rib line attached towards aft, while on the other hand, the lacing line attached to the lower panel tends to pull up point A′, which results in still poorer bottom contact of the footrope.

Four-panel bottom trawlnet

This four-panel net (fig 3) is an improved version of the old two-boat trawlnet and designed to prevent distortion, even at high towing speeds, by decreasing the rate of taper. The more slender shape of the body which the two-panel net did not have improves the catching efficiency by reducing to a minimum the difference between inner and outer flow speed. Like the two-panel net type, this four-panel net should also have a relatively longer headline (CB) in relation to the footrope (DB′), but the bottom contact of point A′ will still be poor unless the footrope is made relatively longer than the headline. This would put the main tension on the headline which makes a high net opening inevitably difficult to achieve.

Six-panel bottom trawlnet

This net (fig 4) is an improved version of the four-panel net in which additional netting has been added as shown in (iii) of the fig 4, so that the resistance of the net as transmitted to the rib lines is removed as far as possible

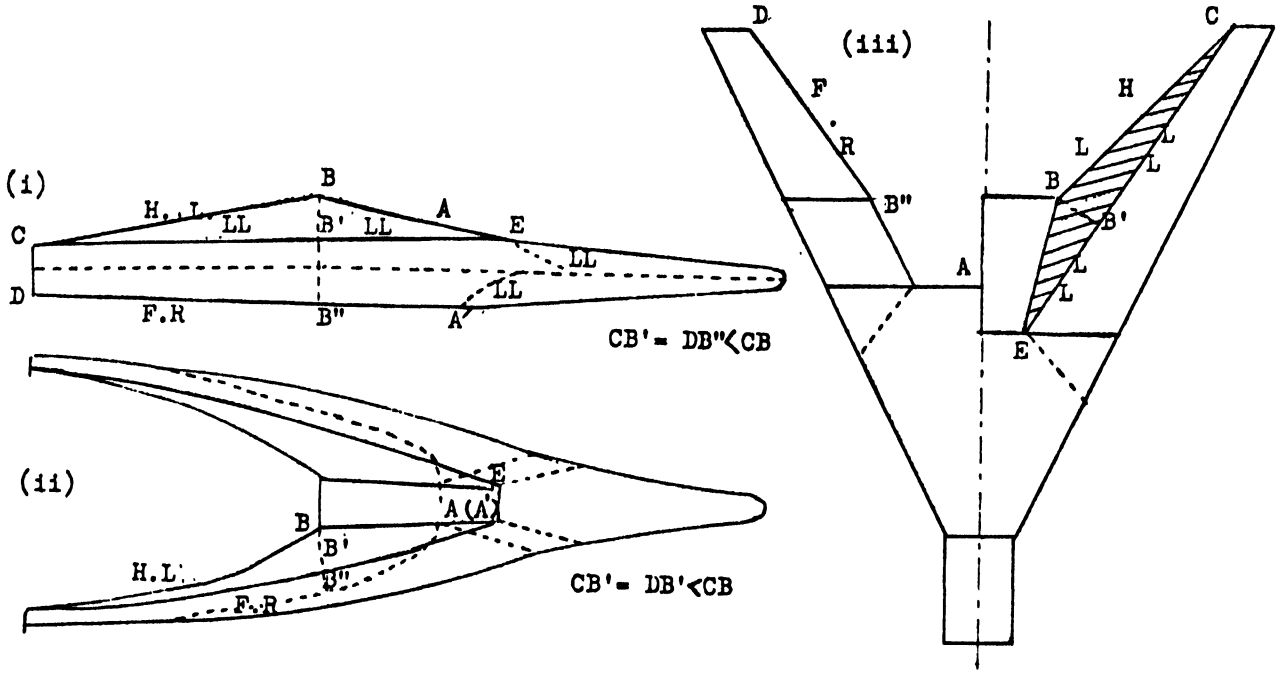


Fig 2. Improved two-panel bottom trawlnet

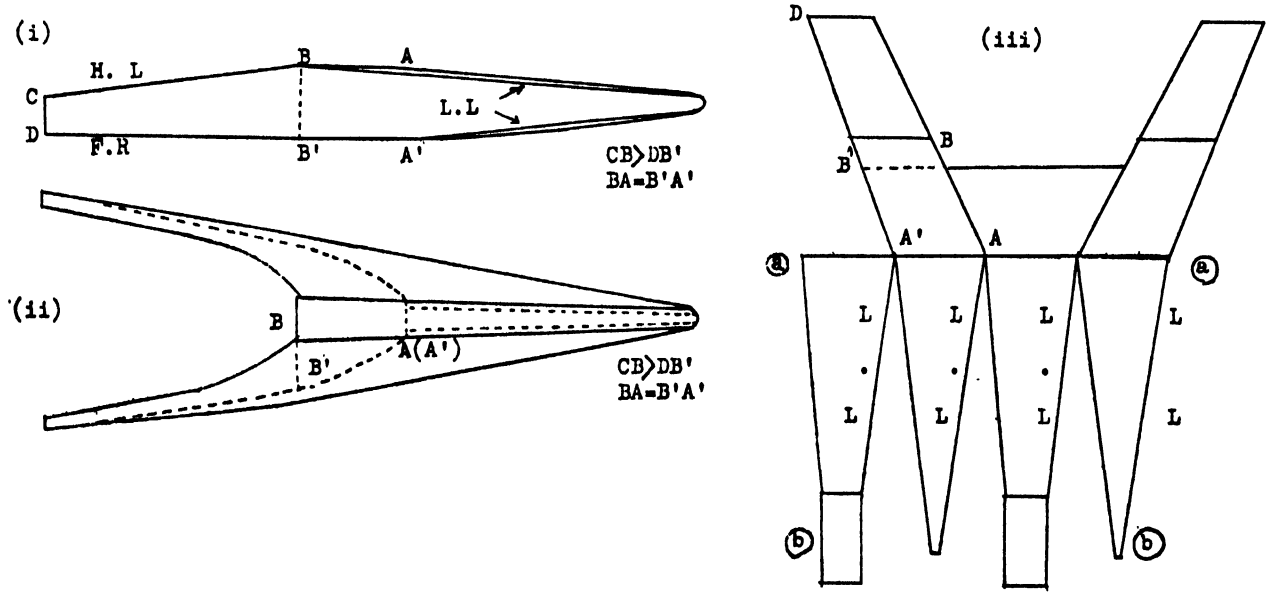


Fig 3. Four-panel bottom trawlnet

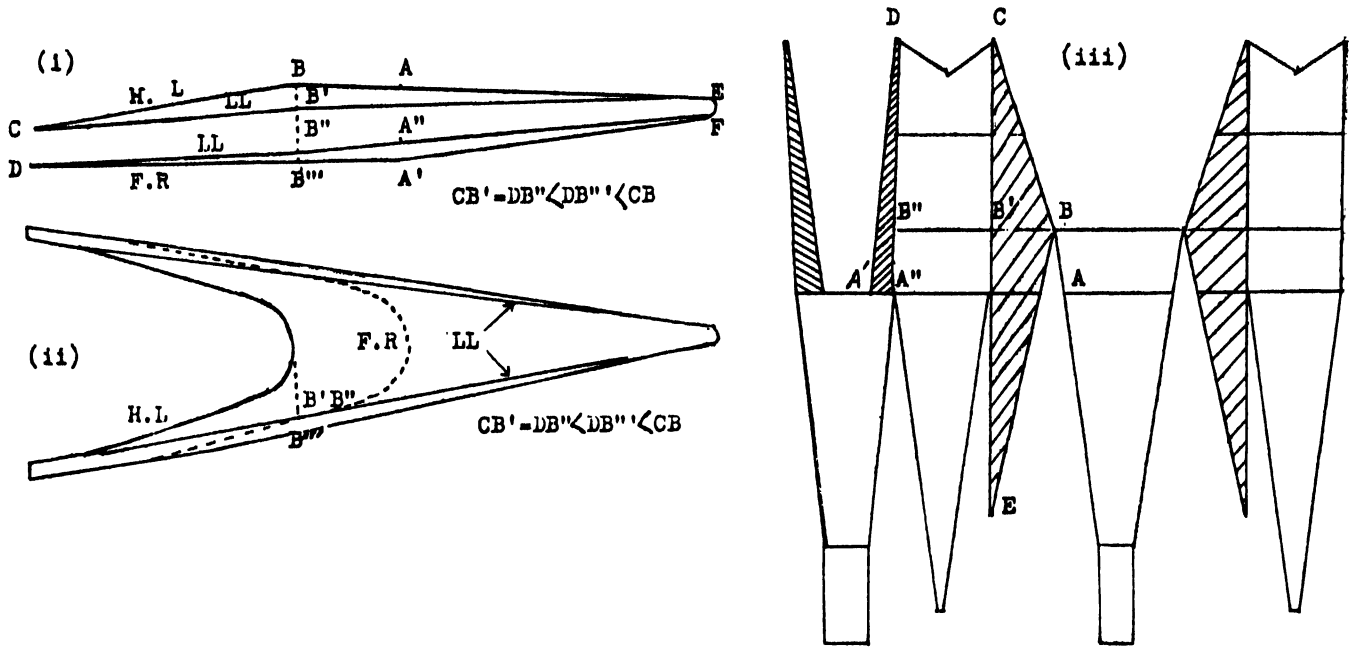


Fig 4. Six-panel bottom trawlnet

from the mid-part of the headline toward the wing tips. This gives slack to the headline to permit a higher opening, at the same time avoiding distortions and maintaining good net shape, even with changes in the width between the wing tips. The triangular netting is given enough slack to prevent straining even at high net opening. The lower rib lines enhance the stability of the footrope; the resistance of the net is transmitted to the lower rib lines which hold the footrope down to the bottom at all times.

The problem of stability of point A′ of the two-panel and four-panel trawlnets is solved by extending the lower rib lines to the fore wing. Since the headline, too, is relatively longer than the footrope and, moreover, since the resistance forces of the net fall almost completely on the rib lines, the triangular netting (CBE) rises very easily. Moreover, the triangular netting DA′ A″ droops easily to give the footrope a high degree of stability at the bottom. However, since this triangular netting is subject to severe wear and tear from scraping on the ground, the lower rib lines are extended to point B‴ to prevent damaging the net when towing over rough bottom. In such case, point B‴ will tend to lift, so there is need for making adjustments by weighting with chains, etc.

Rib lines

The rib lines were originally meant to strengthen the netting for hauling-in. Their function has been extended to increase the height of the net opening by better distributing the towing forces which had previously been concentrated on the headline and the footrope. To achieve this it was inevitable to increase the number of the net panels.

A characteristic of the six-panel bottom trawlnet as compared with the two-panel type is the distribution of the towing forces on four rib lines in addition to headline and footrope. This redirects the tension that would otherwise prevent the net mouth from opening fully. The height of the net opening can thus be controlled to a certain extent by means of modifying the panel and rib line composition of a net and it is further possible by means of the rib lines to give the desired stretch to the meshes in all parts of the net for relatively good filtering ability, efficient filling out of the net, and avoidance of distortion.

With the six-panel net in which the towing tension is better distributed with rib lines, the size of the net can be increased by using thinner net twine than is required for the two-panel nets.

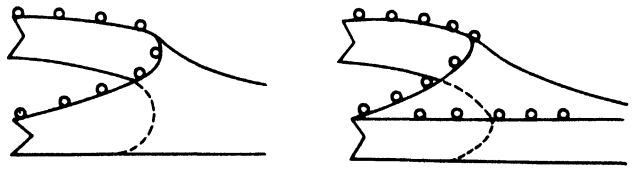


Fig 5. Distribution of floats on two-panel (left) and six-panel bottom trawlnets

While with the two-panel net floats can be attached only to the headline, the six-panel net can take floats on part of the rib lines as well, which means that the height of the net mouth as a whole can be increased (fig 5).

New type bottom trawlnet for large stern trawlers

The bottom trawlnet for large stern trawlers (fig 6) incorporates the desirable features of the various net types described above and represents the latest development in the company's efforts to evolve the most effective bottom trawlnet. This net is regarded as more or less satisfying the essential requirements of net opening, net performance and footrope stability.

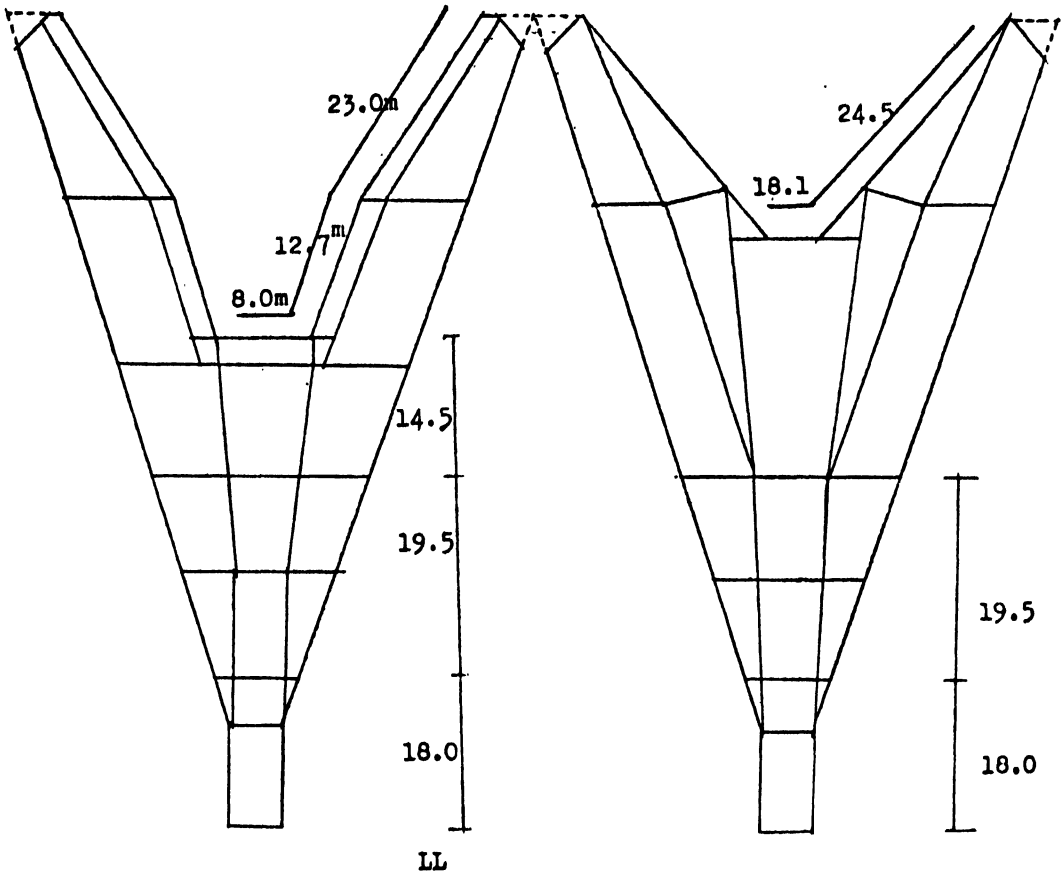


Fig 6. New type bottom trawlnet for large stern trawlers

Since the net opening becomes increasingly favourable as the cross-section approaches a circle, both the belly and the baiting have been divided into three equal longitudinal panels. These panels have been so designed that they can all be used interchangeably in the left, right or centre position, in order to facilitate replacement of damaged parts.

The opening of this new net is extremely efficient for the same reason that a parachute which is made up of equal sized pieces of equilateral triangular cloths opens up so well.

Arrangement of the rib lines is an important consideration for increasing the height of the net opening. Unlike the method used in the past, the rib lines on both the belly and baiting sides are extended separately into the codend (an arrangement closely resembling that of a six-panel net). The hanging coefficient of the rib lines on both the belly and baiting sides has been reduced to almost nil to give good stability to the footrope.

The following table gives the results of 1:15 scale model test of the new trawl net. The values shown have been converted to full size.

TABLE 1

Towing Speed	*Width between Wing Tips*	*Height of Net Opening With Kite*	*Height of Net Opening Without Kite*
3.5 kn	25 m (82 ft)	11.7 m (38.4 ft)	9.4 m (30.8 ft)
4.0 kn	25 m (82 ft)	10.5 m (34.4 ft)	8.4 m (27.6 ft)
3.5 kn	28 m (34.1 ft)	10.4 m (34.1 ft)	8.7 m (28.5 ft)
4.0 kn	28 m (34.1 ft)	9.5 m (31.1 ft)	7.5 m (24.6 ft)
3.5 kn	30 m (98 ft)	9.6 m (31.5 ft)	7.5 m (24.6 ft)
4.0 kn	30 m (98 ft)	8.7 m (28.5 ft)	6.9 m (22.6 ft)

Conditions: Buoyancy of floats 1,000 kgf (2,205 lbf)
Gravity force 1,200 kgf (2,645 lbf)
Bridle 80 m (262 ft)
Kite 2×1 m^2 (2×11.1 ft^2)

MIDWATER TRAWLNET

The spreading use of fish finder echosounders brought to light the fact that almost all fish ascended from or descended to the bottom according to the time of day or season and that the vertical distribution of some species of fish ranged between 20 to 30 m (65 to 98 ft) off bottom or even more, making it unrewarding to trawl on the bottom with a net opening of only 10 m (33 ft) height.

However, midwater trawling cannot operate successfully unless a method is used to tow the net in midwater or just off bottom to catch fish schools that have been found by the fish finder and unless there are means to know whether the net was passing through the aimed schools of fish.

The cable netsonde, forerunner of the more advanced cableless version, came into use as a powerful fishing aid from 1959 and gave impetus to the development of midwater trawling techniques. The presence of the electrical cable however, proved a nuisance when taking in or paying out the warp to adjust the net depth, and the frequent occurrence of breakage or shorting of the

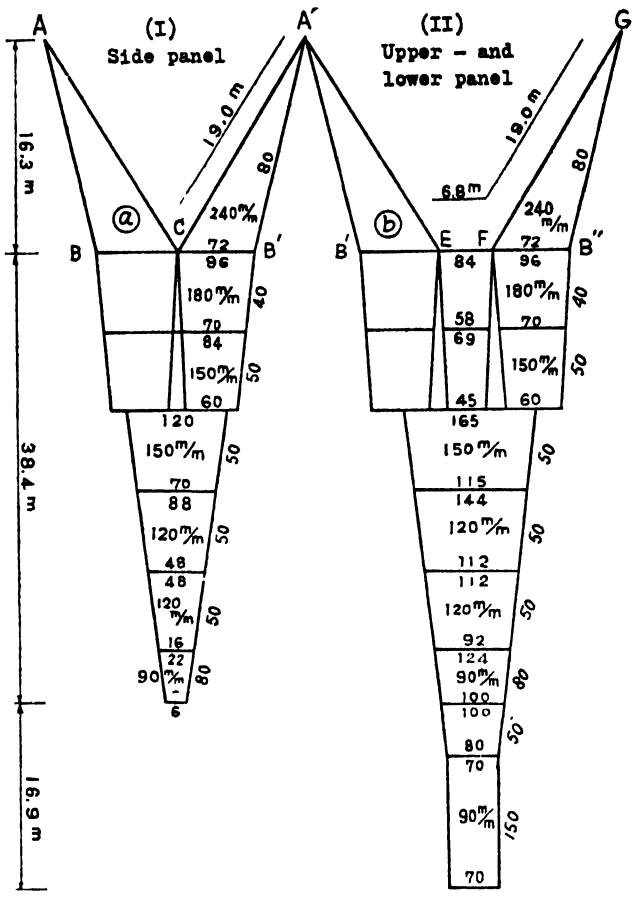


Fig 7. Basic design of a midwater trawlnet for 3,500 ton stern trawler

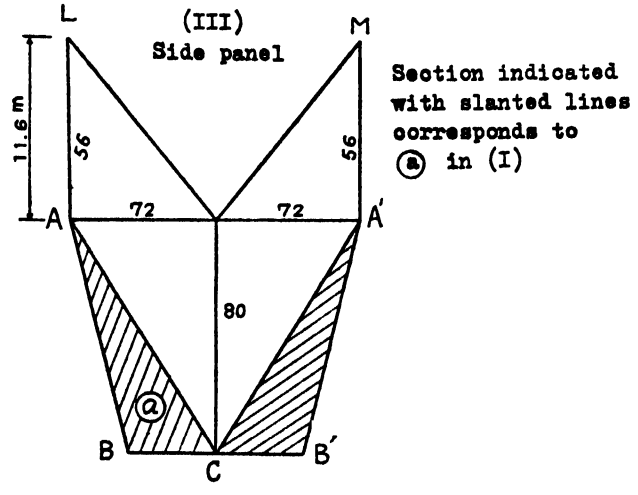


Fig 8. Additional front section of side panels for bottom trawling

cable seriously hampered the progress of midwater trawling.

Subsequently, with the development of the cableless netsonde in 1965, it became possible to determine the position of the net at will over a vertical range of 100 m (328 ft) off bottom and also to estimate the size of the schools of fish entering the net similarly as with the cable type.

In order to catch schools of fish effectively in midwater trawling, a net of different performance is required. As

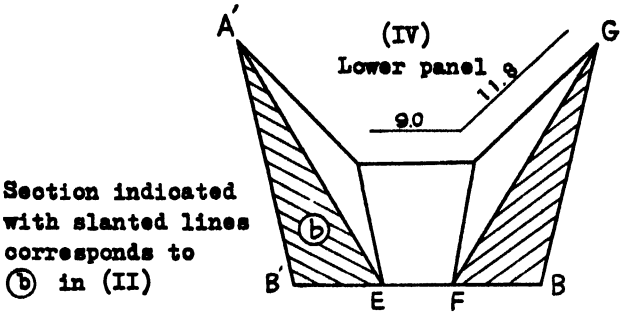


Fig 9. Front-belly extension for mid-water trawling

midwater fish are generally sparsely distributed and quick of movement and since it was also necessary to have a good chance of the net hitting the centre of the fish schools our primary goal was to develop as high and wide an opening as possible also at high towing speed (4.0 to 4.5 kn).

In order to satisfy these conflicting conditions, it was considered necessary to keep the netting area to a minimum and seek to achieve a rational design for good net performance, to adopt as large a mesh size as possible within the limits of preventing the escape of fish, and to use as thin a twine as possible with high strength.

To boost the operation efficiency of midwater trawling, buoyancy and gravity force must be achieved with the use of the simplest possible means of high durability; therefore, such gadgets as depressors and kites were not considered.

The shape of the net should be conical and the wings short so as to enable maximum speed of ascent and descent. Consideration was given to design the wings and footrope in such a way that the net can be used also for bottom trawling.

As some species of midwater fish have the habit of fleeing in a downward direction at great speed when frightened by the wings, the front belly netting should be so constructed as to permit easy attachment and detachment.

Based on the above considerations, five alternative types of net were designed and subjected to a series of model tests in tanks and at sea, and the design which emerged as the final version after the tests is shown in figs 7 to 9.

As stated earlier about bottom trawlnets, the upper part of the side panel is divided lengthwise in two parts and the upper and lower panels are divided lengthwise in three parts, the objective being to attain the best possible opening of the net mouth. The wings (iii) are so constructed as to enable an attachment of netting to be made at ACA′ and at A′EFG (iv) of the lower panel to intercept downward moving fish schools. The additional netting can be readily attached or detached as required.

AUXILIARY FISHING GEAR AND THEIR EFFECT

Auxiliary fishing gear, such as floats, kites, footropes and otter boards are essential for successful operation and these of course have also been subjected to improvement efforts.

Buoyancy

For buoyancy mostly spherical floats of polyester resin are used, although every effort is made to employ kites when towing at speeds exceeding 3.5 kn. In order to obtain equivalent lift to counteract the resistance of the net which increases roughly in proportion to the square of the towing speed, it is necessary to utilize the lifting power of kites.

Floats. With spherical floats the towing resistance increases roughly with the square of the diameter. Since the buoyancy increases with the third power of the diameter the efficiency of spherical floats mounts rapidly with increasing size. The following table gives the relationship between the buoyancy of various size floats and the towing resistance (values are experimental values):

TABLE 2. POLYESTER RESIN FLOATS FOR 500 m (1640 ft) DEPTH

Diameter	*Buoyancy kgf/(lbf)*	*Resistance kgf/(lbf)* 3.0 kn	3.5 kn	4.0 kn
150 mm (5.9 in)	1.35 (3.0)	3.2 (7.0)	4.1 (9.0)	5.3 (11.7)
200 mm (7.9 in)	3.26 (7.2)	3.3 (7.3)	4.3 (9.5)	5.6 (12.3)
240 mm (9.5 in)	5.70 (12.6)	3.5 (7.7)	4.8 (10.6)	6.2 (13.7)
360 mm (11.8 in)	10.94 (24.1)	4.2 (9.2)	5.7 (12.6)	7.4 (16.3)
360 mm (14.2 in)	18.04 (39.8)	5.7 (12.6)	7.5 (16.5)	10.0 (22.0)

The number of floats required to obtain a total buoyancy of 1,000 kgf (2,205 lbf) on the basis of the values given in the foregoing table is shown in the following table, together with the resistance in relation to towing speed. These values clearly indicate the superior efficiency of larger sized floats.

TABLE 3

Diameter		150 mm (5.9″)	200 mm (7.9″)	240 mm (9.5″)	300 mm (11.8″)	360 mm (14.2″)
No. of floats		750	306	176	92	56
Resistance at 3.0 kn	kgf (lbf)	2360 (5203)	1020 (2249)	620 (1367)	380 (837)	320 (705)
Resistance at 3.5 kn	kgf (lbf)	3040 (6702)	1320 (2910)	840 (1852)	520 (1146)	420 (926)
Resistance at 4.0 kn	kgf (lbf)	3920 (8642)	1720 (3792)	1100 (2425)	680 (1499)	560 (1235)

Consequently, our larger trawlers never used floats of less than 300 mm (11.8 in) diam and are presently using floats of 360 mm (14.2 in) diam. When the technical problem of pressure resistance at depths of 800 to 1,000 m (2,625 to 3,281 ft) is solved, we hope to start using floats of 450 mm (17.7 in) diam.

Kites. With increasing net size and towing speed (4.0 to 4.5 kn) of the larger and larger trawlers, due to the influence of towing resistance proper performance of the net cannot be maintained with floats alone. Kites are more suitable because their lifting force increases roughly in proportion with the square of the towing speed.

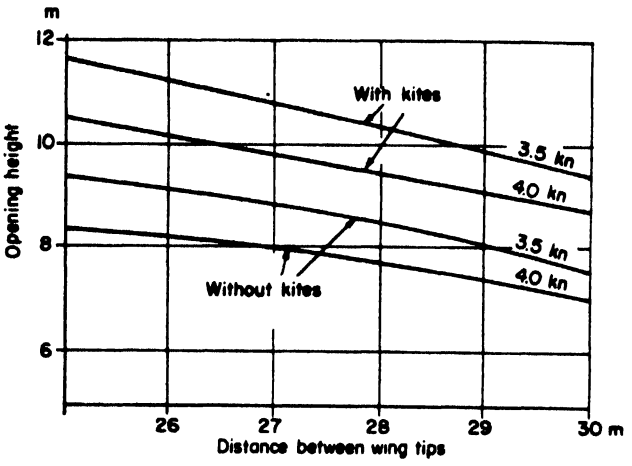


Fig 10. Comparison of the opening height of a large bottom trawlnet with and without two kites of 1 m² (11.1 ft²) each

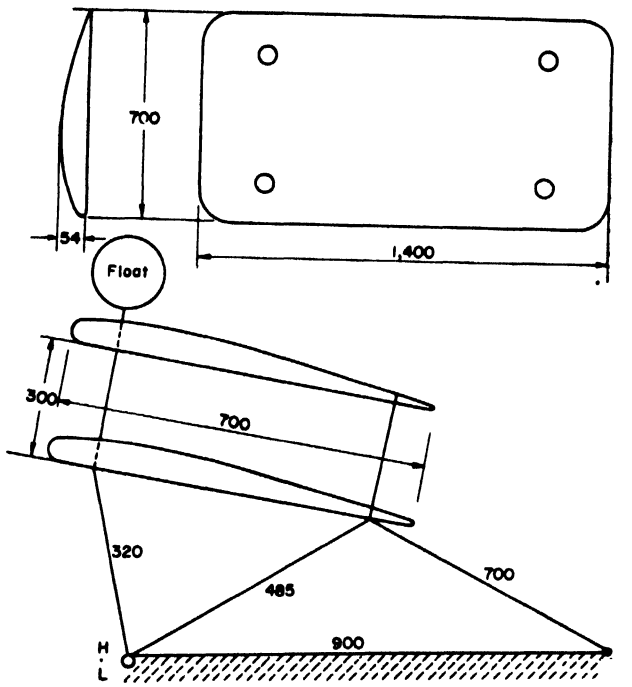


Fig 11. Shape and dimensions of hydrofoil kite and double kite arrangement at the leadline bosom. Dimensions in mm

In the tests conducted with the trawlnet of 4,000-ton stern trawlers with kites an increase of approximately 2 m (6.6 ft) in the opening height was obtained (figs 10 and 11).

The lifting force of a kite of 1 m² (11.1 ft²) size is as shown in Table 4.

TABLE 4

Towing Speed	kn	3.0	3.5	4.0	4.5
Lifting force	kgf (lbf)	145 (320)	175 (386)	255 (562)	320 (705)

Otter boards

After 1956, the square, flat otter board type was rapidly abandoned in favour of hydrofoil otter boards which have a decidedly superior lift to drag ratio.

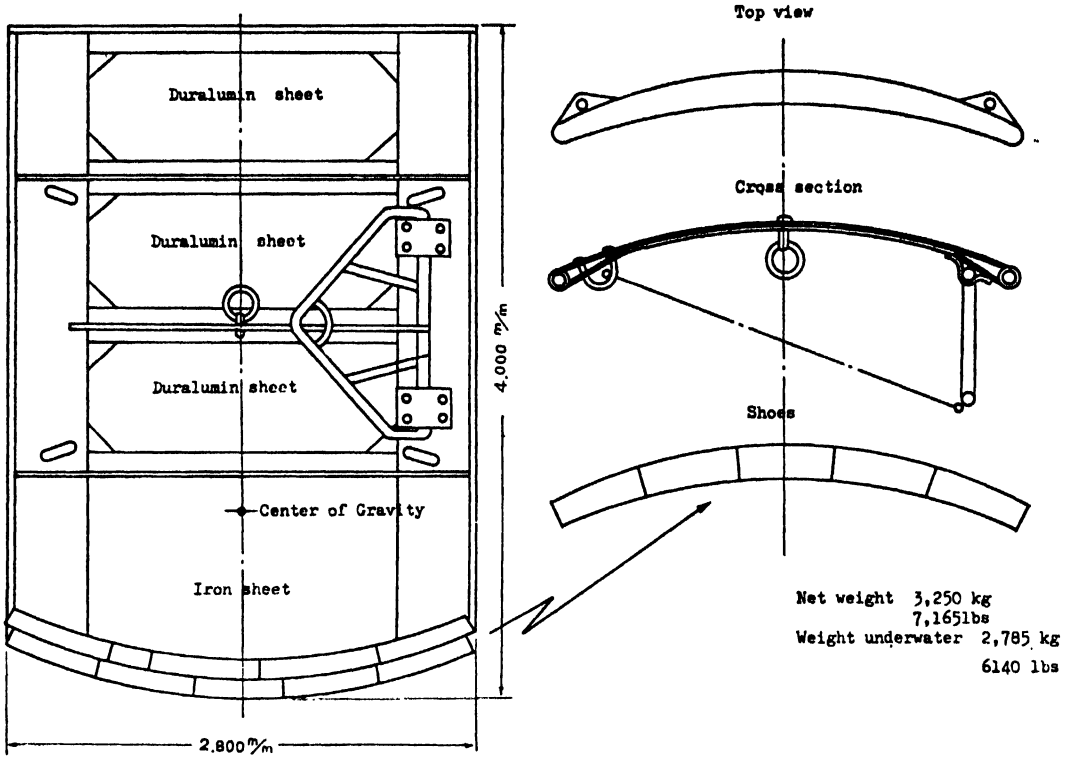


Fig 12. Hydrofoil otter board for 4,000 ton stern trawler

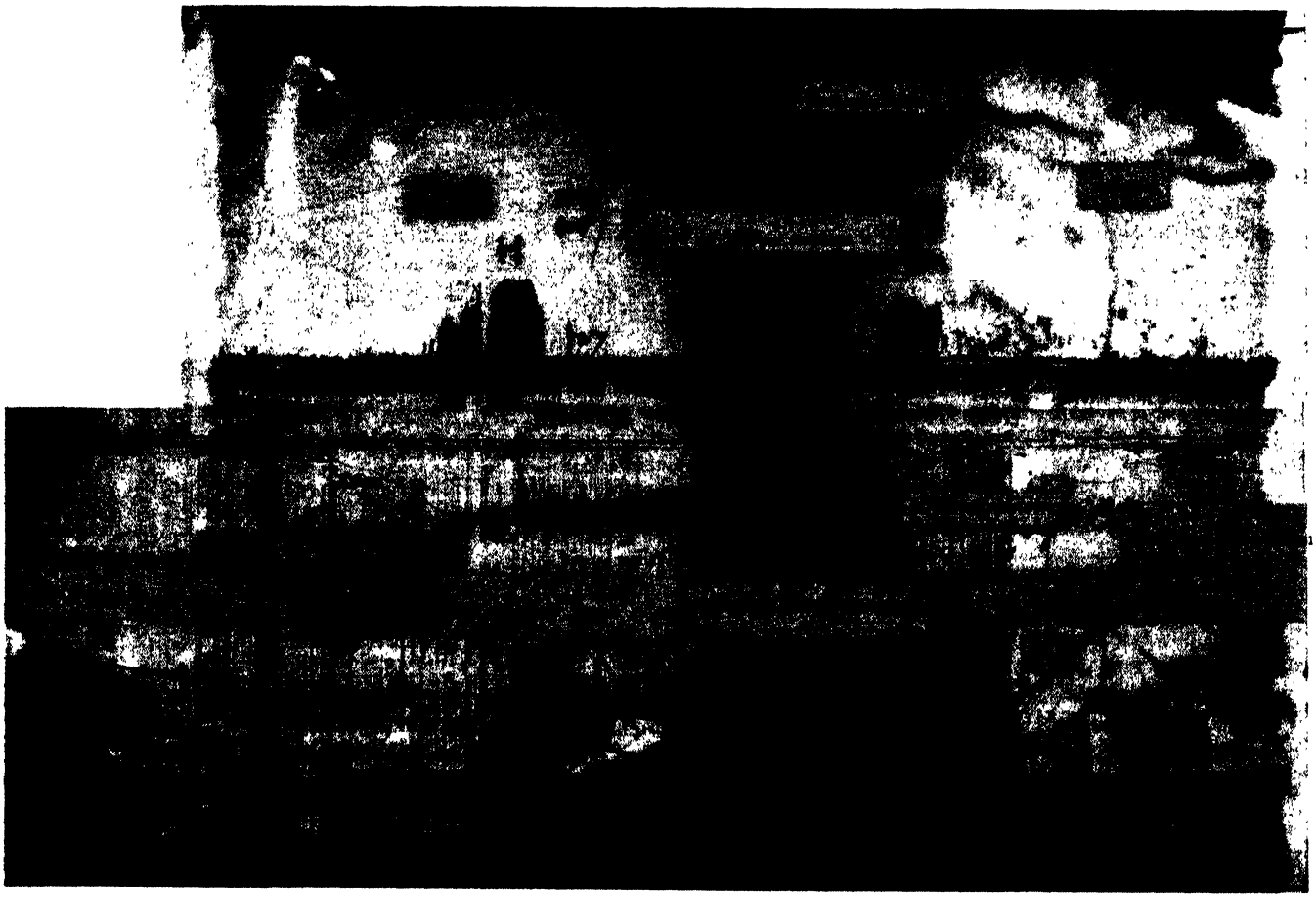


Fig 13. Typical herring school traces from the Bering Sea. Above, searching at 12 kn, below, midwater trawling for the same schools (D to H) with the course of the net drawn in according to the netsonde recording (Fig 14). Paper transport is from left to right, i.e. recording from right

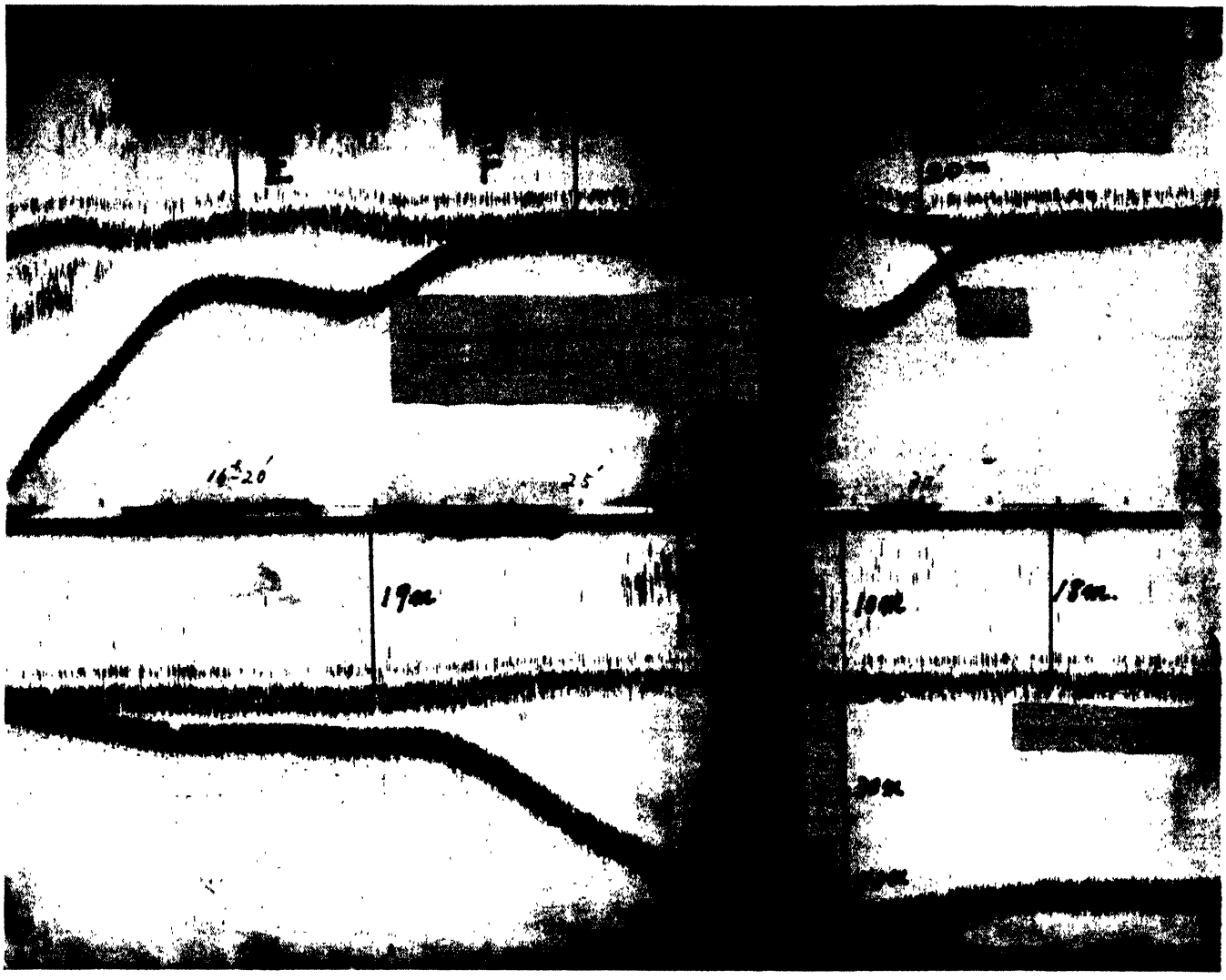


Fig 14. Netsonde echogram of the midwater tow; ship's sounder echogram shown in Fig 13. Paper transport is from right to left

The important features of an otter board are its shape, weight under water, and position of the centre of gravity. Iron and duralumin have been adopted as suitable structural materials. As the boards for large trawlers are as large as 4 m (13.1 ft) high by 2.8 m (9.2 ft) wide, it is essential that they be of very strong construction. Steel pipes of adequate diameter and thickness are used on both sides of the otter board to prevent bending or twisting. In order to lower the centre of gravity the upper two-thirds of the board are planked with duralumin sheet and the lower third with iron plate. Thick, manganese steel material is used for shoes at the bottom edge which are constantly in contact with the sea bottom, and these shoes are sectioned to facilitate partial replacement as required.

Otter boards built to the above-described specifications are being used on rough bottoms of the North Pacific and elsewhere and are amply demonstrating their worth in point of efficiency and durability.

The otter boards most commonly used by our company fleet have an aspect ratio of 2.0 to 1.3 and a camber of 12 to 13 per cent. Lately, the tendency is towards an aspect ratio of 1.5 to 1.3 because of better manoeuvrability when shooting the net and better stability under tow (fig 12).

MIDWATER TRAWLING FOR HERRING

For herring midwater trawling in the Bering Sea the net shown in figs 7 to 9 is used. Typical conditions are as follows:

One 1-m² (11.1 ft²) kite having a lifting force of about 870 kgf (1,918 lbf)
Vertical gravity force—1,040 kgf (2,293 lbf)
Length of warp —300 to 320 m (984 to 1,050 ft)
Towing speed —3.7 to 4.0 kn

The ship's sounder echograms (fig 13) shows the herring schools *D*, *E*, *F*, *G* and *H* detected during searching at a speed of 12 kn. The net was shot immediately on reverse course and towed from school *H* to school *D*, but no fish was caught according to the netsonde the records of which are omitted here. As the evening was fast approaching and the herring schools would soon be ascending and dispersing, it was feared that the chance

would be lost if the net were to be hauled up to make a renewed search with the fish finder. It was therefore decided to turn round with the net in the water for another sweep over the same course. As can be seen from the lower echogram (fig 13), the second tow was made from schools *D* to *H*, keeping the net trained on the schools by adjusting the revolution of the main engine. As can be seen from the netsonde echograms (fig 14), this time good amounts of fish entered the net. It was estimated that the catch would be about 30 t but it actually amounted to 55 t of large herring.

Ship's sounder and netsonde echograms show that the net coincided with the position of the fish schools with almost perfect accuracy. The height of the net opening was between 18 and 20 m (59 to 65.6 ft) throughout the tow.

The fish school *D* was missed completely, as it passed under the net before it could be fully lowered.

Instrument Controlled Midwater Trawling Tactics in the Atlantic and Adjacent Seas

V. I. Savrasov

Chalutage pelagique controle par instruments dans l'Atlantique et ses mers adjacentes

L'historique du développement du chalutage pélagique en U.R.S.S. peut être subdivisé en deux phases distinctes: (a) celle des filets à deux faces, d'une hauteur d'ouverture de 8 à 10 m, (b) celle des filets à quatre faces, d'une hauteur d'ouverture de 14 à 18 m. On considère que des chalutiers à force motrice élevée sont nécessaires pour obtenir la vitesse adéquate de remorquage. Pour un chalutage pélagique fructueux, il convient de disposer au préalable à bord de systèmes de détection du poisson et d'un télémètre de profondeur sur le filet. Des télémètres à liaison par câble ou hydroacoustique sans câble sont largement utilisés en U.R.S.S. et dans d'autres pays. Des études généralisées et systématiques sur le comportement du poisson sur les lieux de pêche, à l'aide d'observations visuelles ou intrumentales, sont indispensables pour l'amélioration de la conception des chaluts pélagiques en vue d'une efficacité accrue. L'influence de plusieurs facteurs sur le rendement de pêche est discutée, parmi ceux-ci: la dimension de l'ouverture du chalut; la grandeur des mailles dans les différentes parties du filet; et la vitesse du chalut pendant le virage.

Métodos para la pesca al arrastre entre dos aguas, controlada con instrumentos, en el Atlantico y mares adyacentes

Históricamente, la evolución de la pesca al arrastre entre dos aguas en la U.R.S.S. puede subdividirse en dos etapas: (a) redes de dos seccones, con abertura vertical de 8 a 10 m, (b) redes de cuatro seccones, con abertura vertical de 14 a 18 m. Para obtener una volocidad adecuada de remolque son necesarios arrastreros con motores de gran potencia. Los dos requisitos necesarios para que la pesca al arrastre entre dos aguas tenga éxito son aparatos para la localización de peces y un batitelémetro en la red. En la U.R.S.S. y en otros países se usan a menudo batitelémetros hidroacústicos instalados en la red y en comunicación con el barco por cable o inalámbricamente. El estudio del comportamiento de los peces en los caladeros con ayuda de observaciones visuales e instrumentales, así como la generalización y sistemación de dichas observaciones, son esenciales para mejorar el diseño de los artes pelágicos de arrastre e incrementar su rendimiento. Se examina la influencia en la eficacia de la captura de varios factores, tales como: la abertura de la red de arrastre; el tamaño de las mallas en diversas partes de la red; y la velocidad de halado de la red.

THE development of pelagic fishing took place in two major stages. The first stage was during the 1940's and 1950's when fishing vessels were equipped with acoustic search devices. During this period both two- and four-panel trawls were used for operations on and near the bottom. However, to catch schools in midwater, it was necessary to change the fishing gear parameters. Consequently, midwater trawls with an opening of 400 sq m and even exceeding this figure were designed during this period.

The second stage of development occurred during the 1960's when control devices for trawl operation were developed. These permitted accumulation of information on fish behaviour in relation to the gear and permitted control of the trawl while towing. This led to the design of trawling gear characterized by four-panel trawls with a large opening and wing-shaped otter boards.

Trawling gear employed by Soviet fishing vessels

Trawling gear and its rigging differ in relation to fish species and their behaviour which affect cable length used, size of mesh in different parts of the trawl and dimensions of the opening. The most widely used trawl in the U.S.S.R. is 38.5 m and is used on boats with 2000 to 3000 hp. It is operated for fishing both dense and thin schools of herring, scombers, mackerel, greenfish, etc.

Netting

The trawl is constructed of four panels (fig 1). The side panels are narrowed at the end to a single mesh. This feature permits use of a two-piece codend and one of the characteristic features of these trawls is a very wide codend which is attained by using a more gradual taper in cutting the body panels. In experiment and practice it has been established that a wider codend facilitates its emptying and eliminates gilled fish in the throat. The wide codend causes no difficulties in hauling a catch of 30 to 40 T. Longitudinal strength, when no lifts are used, is provided by side seams, which "take in" from 5 to 10 meshes from each net panel.

Rigging

Trawls are equipped with two pairs of bridles (70 to 100 m) extending from otter boards to net. The lower

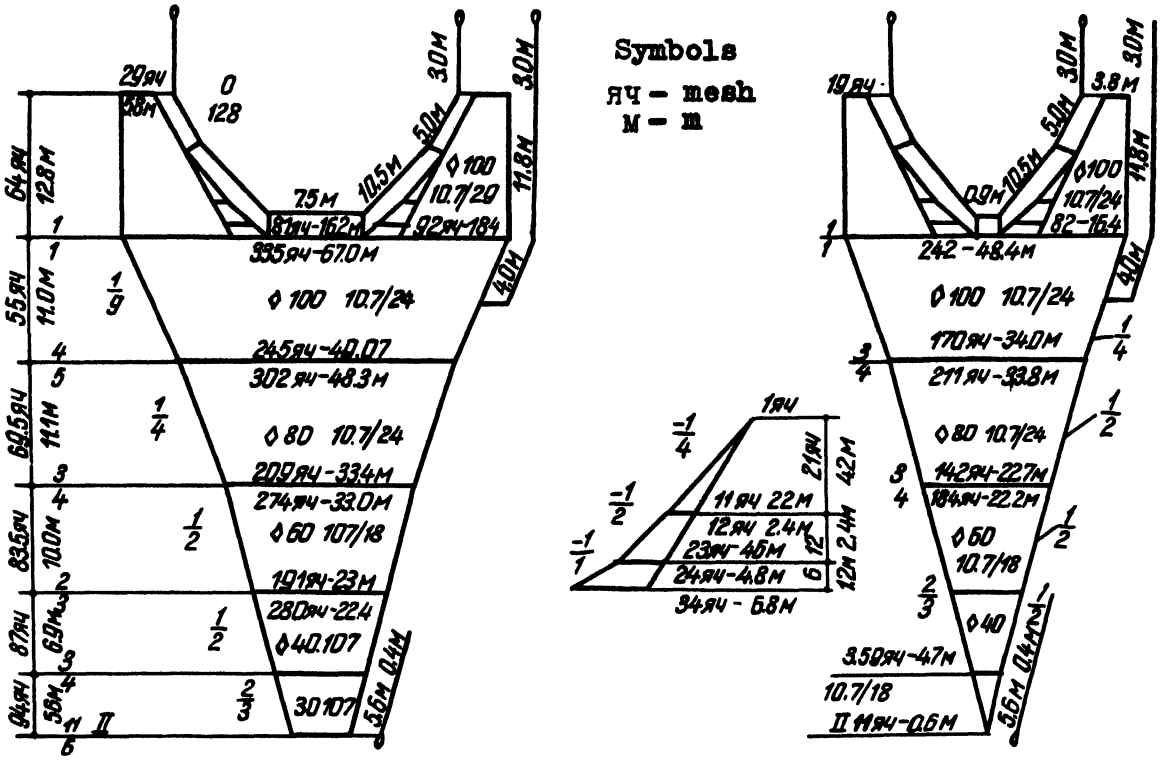


Fig 1. Construction of a U.S.S.R. midwater trawlnet of 38.5 m

cables are one to two per cent longer than upper ones (fig 2). To obtain required vertical opening and to prevent cable twisting, concentrated weights of 450 to 500 kg are applied as shown. The footrope is also weighted. The total of this weight is theoretically equal to buoyancy on the headline. Plastic and metal floats with static or hydrodynamic lifting power are used. This rigging provides the trawl with a high vertical opening and the footrope operates 15 to 20 m lower than the otter board.

Control devices

Devices intended to monitor the performance of a pelagic trawl provide continuous information on trawl depth in relation to fish schools, vertical opening of mouth and fish behaviour within fishing zone. This information permits adjustments in depth or speed, which increase efficiency. Two basic types are used in U.S.S.R. One is with an echo sounder mounted on the headline of the trawl with an electrical conductor from net to vessel. This is the ITEK system and is used on larger trawlers. The basic technical specifications are:

Range of measured depth—10 to 600 m
Length of communication cable—1800 to 2200 m
Breaking load of communication cable—2 tonf
Maximum speed of cable pay out—5 m/s
Maximum speed of cable hauling—2 m/s
Nominal power used during hauling—8 kW

The other system is the "Glubina" which is a pressure sensing device mounted on the net and using an acoustic signal to transmit depth information to the digital read-out instrumentation on the vessel—used on smaller vessels (fig 3).

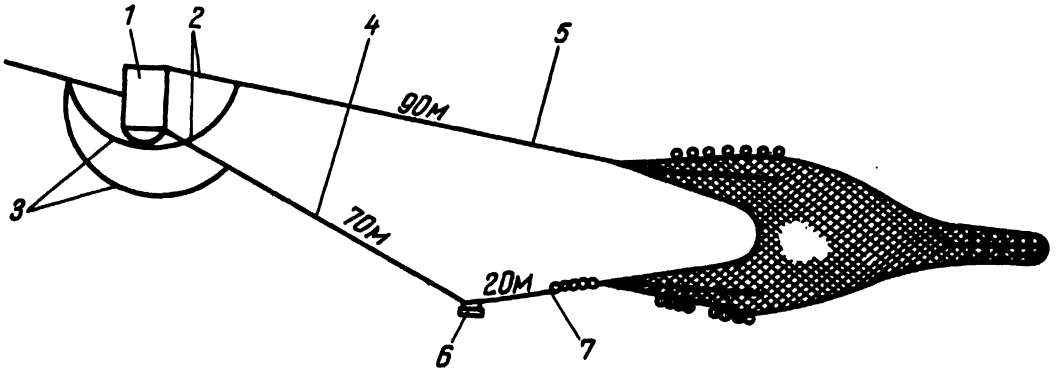


Fig 2. Rigging scheme
1 = curved otter board 2 = backstrops 3 = pennants 4 = lower bridle 5 = upper bridle 6 = frontweight 7 = wingtip weight

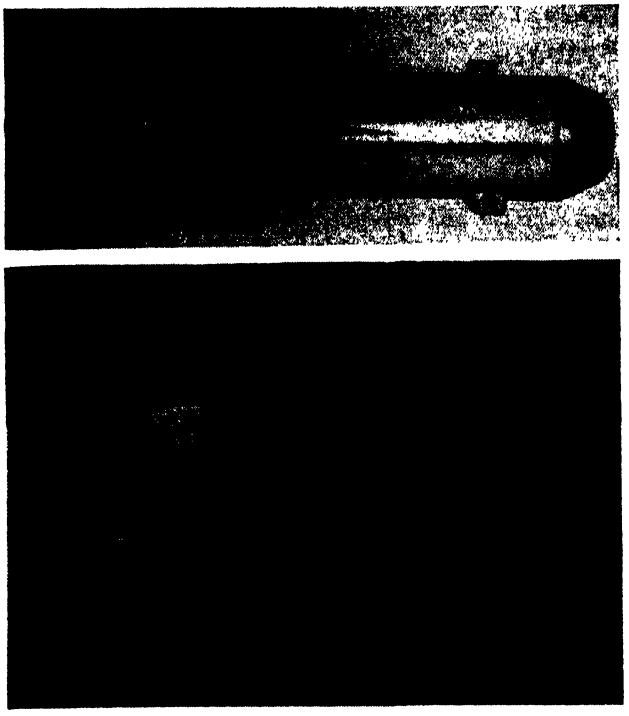


Fig 3. Acoustic depth telemeter Glubina. Net unit (above) and receiving hydrophone (below)

Effect of fish behaviour on fishing gear design

Thanks to means of underwater observation, man's knowledge of fish behaviour and its relation to the design of fishing gear has progressed substantially. Observations in the U.S.S.R. show that the trawlnet has three zones for fish behaviour. First is the wing and mouth area where fish show little response. They move with the trawl, keeping 1 to 2 m from the netting. The fish's swimming speed exceeds that of the trawl at a rate of 0.05 to 1.5 m/s. However, their forward movement at high speed lasts only a few seconds and there were no attempts to escape through the netting. An increase of trawling speed from 3.5 to 5.0 kn results in a change of speed of the fish school and their movement with the trawl may last for quite a time ranging from 0.5 to 1 h. In this, some fish tire and gradually fall behind and roll into the codend. Flatfish, skate and other species regarded as bottom dwellers try to escape beneath the footrope providing there is space.

The second zone is the end of the belly and the beginning of the codend where the net panels are at a distance of only 2 to 3 m from each other. Fish in this zone display active behaviour and try to go through the netting or to swim ahead to escape. Some of the fishes, probably tired, roll into the codend.

The third zone is the end of the codend where there is a circular motion of water masses. In this area, fish offer little resistance to the current and are either carried away by it or pressed to the netting.

Fish density varies in different zones of the trawl. In the front it amounts to about 20 fish per cubic metre; in the midpart of the belly the rate is 40 to 50 and in the conic part of the trawl bag the figure reaches 70 to 80 per cubic metre. These observations pertain to mackerel (*Decapterus punctatus*), sardinella (*Sardinella anchovia*), spot-fin croaker (*H. parra*), stone perches (*Mysteropera venenosa*).

Factors affecting the catch of pelagic trawls

The productivity of trawling depends on two groups of factors—biological and technical. The biological factors include range of fish sight, acuteness of their reaction to fishing gear, and muscular energy in avoiding the gear.

The technical factors deal with size of trawl opening, rate of trawl hauling, mesh size in different parts of gear and size of separate gear units, etc.

Fish in the catching zone vary in their behaviour. This is conditioned by the particular zone of the trawl and depends on the distance between the net walls. There is also a critical zone beyond which fish attempt to escape through meshes. Estimation of the size of this critical zone would permit the choice of suitable mesh sizes in different trawl zones and would have a pronounced effect on efficiency. The observations indicate that most sizes in the wings and forward parts of the belly may be increased two to three times over those presently used. At the end of the belly area, at the beginning of the codend and in the codend proper, the mesh size ought to permit escape of fish below commercial sizes.

Instrumented and visual observations confirm that escapement occurs through the mouth opening during hauling. To reduce this a "flapper" of netting is sometimes installed at the front of the codend. Another possibility is a faster hauling speed. The actual hauling speed should be no less than its speed while fishing. Warp hauling speeds to achieve this should be within 110 to 130 m/min.

Two-boat Bottom and Midwater Trawling

R. Steinberg

Chalutage a boeufs au fond et entre deux eaux

Dans certaines conditions de pêche il est avantageux d'utiliser des chaluts à grande ouverture. Dans le cas des plus petits chalutiers de très faible force motrice, les chaluts qui peuvent être utilisés par un seul bateau ont une taille plutôt limitée. Ces bateaux ont la possibilité de remorquer de grands filets en employant la méthode de pêche en boeufs, à la fois pour le fond et entre deux eaux. Le chalutage démersal à boeufs e été important depuis de nombreuses années dans les pêcheries de cotres en Baltique. Des côtres de 150 à 200 ch employent des filets à deux faces avec un bourrelet d'en viron 66 m (200 ft) et une hauteur d'ouverture de 8 à 9 m. Des chaluts de fond à deux bateaux se sont aussi révélés productifs au large des côtes de l'Afrique de l'Ouest tropicale. Ce type de filet a également été utilisé depuis plusieurs années pour la pêche en eau douce. Par l'adoption de la méthode en boeufs, les côtres et les chalutiers moyens peuvent participer utilement à la pêche pélagique qui nécessite de grands filets, lesquels ne pourraient pas normalement être trainés par un seul bateau avec une puissance aussi limitée. Pour la pêche en eau douce, les chaluts-boeufs pélagiques ne peuvent convenir que dans certaines conditions favorables.

Pesca al arrastre de fondo y entre dos aguas en parejas

En ciertas condiciones pesqueras conviene emplear redes de gran abertura de boca. Con los arrastreros más pequeños de poca potencia el tamaño de las redes que se han de emplear en una sola embarcación es bastante limitado. Tales barcos tienen la posibilidad de calar grandes redes empleando el método por parejas en el fondo y entre dos aguas. La pesca al arrastre de fondo en parejas ha sido importanté durante muchos años en la pesquería alemana con cúteres del Báltico. Los barcos de 150 a 200 C.V. emplean redes de dos paños con una relinga de fondo de unos 200 pies (66 metros) y una abertura de boca de 8 a 9 metros. Las redes de fondo en parejas han demonstrado también ser muy útiles en las costas del Africa occidental tropical. Esta clase de red se ha usado también durante muchos años en las pesquerías de agua dulce. Valiéndose del método en paejas, los pesqueros y los arrastreros de medio tamaño puede también tomar parte eficazmente en la pesca al arrastre pelágica para la que hacen falta grandes redes, las cuales normalmente no podría ser haladas por una sola embarcación de tan poca potencia. En la pesquerías de agua dulce, las redes de pesca entre dos aguas en parejas sólo son adecuadas en ciertas condiciones favorables.

THE efficiency of trawls depends, apart from many such factors as net design, towing speed etc., primarily on size of net. Larger nets, however, require more engine power. For this reason trawlers were equipped with more powerful engines. Smaller trawlers, due to limited space and costs, are restricted to a limited increase in engine power. In such cases two-boat trawling is a way out. For this kind of trawling, nets twice the size of normal gear can be used. An additional factor is the elimination of otter board resistance. This results in an efficient net opening which is normally considerably larger than the added efficient opening of two one-boat trawls. Additional efficiency is gained since the trawlers do not pass over the fish nor do the towing warps touch the fish school before it is reached by the net.

However, two-boat trawling also has considerable disadvantages. It is more dependent on favourable weather conditions when passing over ropes during shooting and hauling. Furthermore, the two boats must be approximately equal in size and horsepower and easily manoeuvrable which restricts vessel size. It is also essential that the two captains work well together.

Two-boat trawling naturally only makes sense when the fishing conditions allow a pair of boats to catch considerably more fish than two single comparable trawlers can catch.

Two-boat bottom trawling

The two-boat bottom trawl which preceded the midwater trawl was developed in Germany in 1927 for herring fishing in the Western and Central Baltic. It proved successful from the beginning. Therefore, its use spread rapidly in following years and in the cutter fishery of the Eastern Baltic it was also applied for fishing cod (*Gadus morhua*) and perch-pike (*Lucioperca lucioperca* L.).

The German cutters of the Baltic have on average considerably smaller engine power than those of the North Sea. The Baltic fishery is also less affected by bad weather. Several German cutters with especially well trained crews fish in the Baltic very successfully with this technique the whole year round.

During the last two decades herring was occasionally caught with two-boat bottom trawlers in the North Sea, but this was recently abandoned because of declining stocks.

The two-boat bottom trawlnets are exclusively of two-seam type and their size depends naturally on available towing power. Most German cutters have about 150 to 220 hp and the nets have accordingly a circumference at groundrope bosom of approximately 500 meshes at a mesh size stretched of 160 mm (fig 1). These nets have a footrope length of about 200 to 210 ft (66 to 70 m) and an opening height of about 8 to 9 m. They have the largest opening height of all German two-seam bottom trawls, and are therefore especially suitable for semi-pelagic trawling.

Rigging of German two-boat bottom trawls is shown in fig 2. It is of particular importance to have sufficiently heavy front weights to ensure the net remains close to the ground. The horizontal spreading of the nets is determined by the distance between the two boats.

So far, all German cutters are built as side trawlers. Therefore, first the net, including bridles, is shot from one cutter; then one bridle is transferred to the second cutter and connected to its towing warp and front weight. Then the two cutters turn into the trawling direction and shoot the required length of towing warp. In two-boat trawling, relatively long warps have to be used. If the water depth is shallow the ratio between length of warps and water depth is between 1:10 and 1:15. With greater water depth the ratio decreases somewhat, but is higher than in one-boat trawling.

When hauling the gear at first the towing warps are reeled in, then one bridle without its front weight is released from the towing warp of one boat and is passed

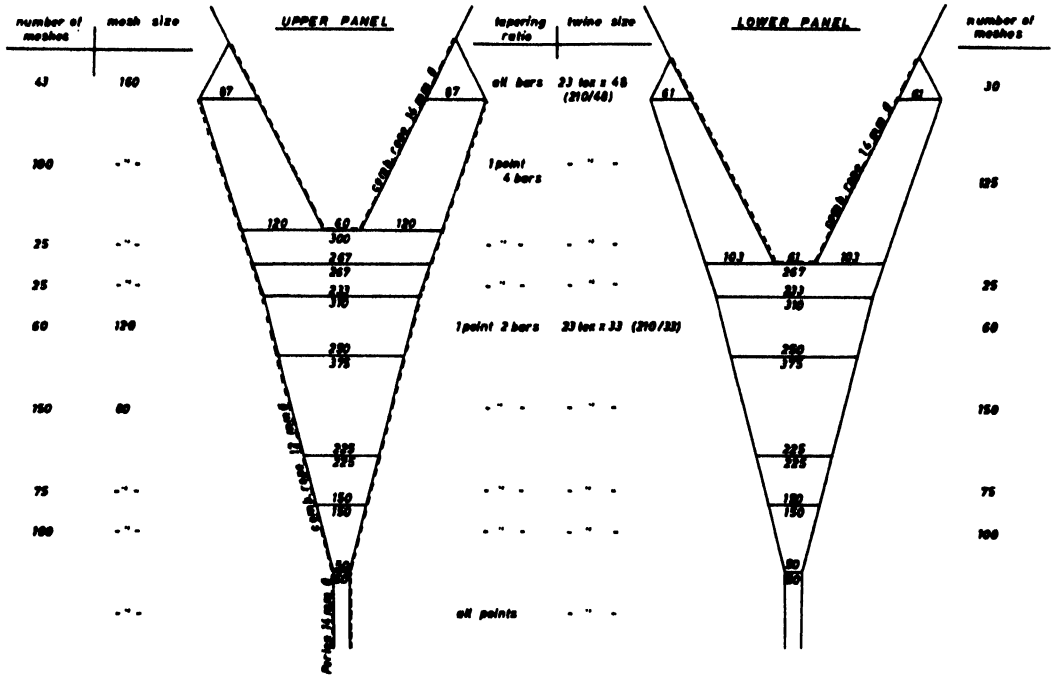


Fig 1. Structure of a 210 ft two-boat bottom trawl for 150 to 200 hp trawlers

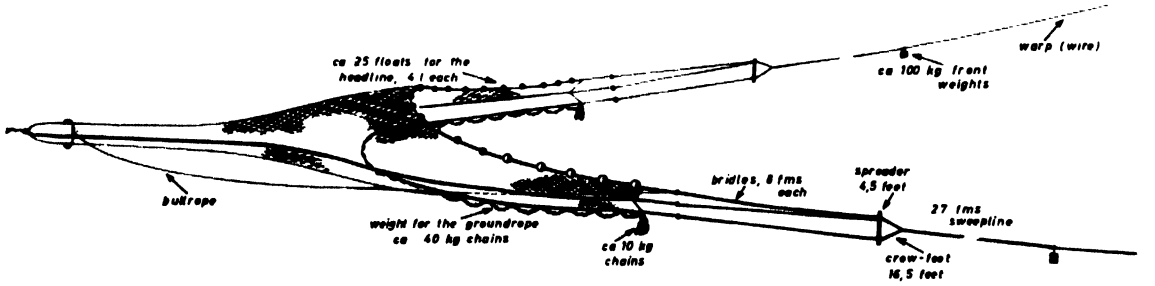


Fig 2. Schematic representation of the rigging for a 200 to 210 ft two-boat bottom trawl

over to the other boat where the net is hauled on board.

During shooting and hauling, most of the work is done by the crew of only one cutter. However, it is customary that part of the crew of the other cutter goes aboard the other vessel and helps.

In 1967 the Federal Republic of Germany carried out a programme of Technical Aid for Developing Countries by introducing modern trawling methods in the fisheries of the Ivory Coast. One of the conventional two-boat bottom trawls used in the Baltic (figs 1 and 2), but with a smaller mesh size in the aft part of the net, was tested under tropical conditions. Of several other nets tested this net was one of the most successful. Compared with local cutters operating with one-boat bottom trawls at the same time on the same grounds catch rates were at least four times and sometimes ten times greater, although neither the captain nor the crews were familiar with the two-boat method. The largest catch made in two and a half hours of trawling was about 3.5 tons of fish. This was then excellent fishing for those grounds. On catch value, comparison was considerably in favour of the two-boat method. Catches of one-boat trawls consisted of about 80 per cent small fish and only 20 per cent large fish. With the two-boat net, this ratio was about 1:1. This favourable catch composition was due mostly to the large opening height of the two-boat trawl which enabled the net to catch many of the larger fishes living off bottom.

In view of these results, this method should be used on a larger scale in the countries of this area, particularly since existing trawlers of these countries are mostly relatively small. Moreover, weather conditions are generally good.

Two-boat bottom trawling in freshwater

The freshwater fishery of the Federal Republic of Germany is forced to improve efficiency because of constantly increasing lack of manpower. Trawling offers one possibility for solving this problem. First experiments were carried out in 1964 in some lakes. As the boats have mostly only small engines (about 10 to 20 hp), the two-boat method was exclusively employed. The main aim was the development of a two-boat bottom trawl for catching eel (*Anguilla anguilla* L.) during the main eel season (May to October). Eel is the most expensive and most important species in this fishery.

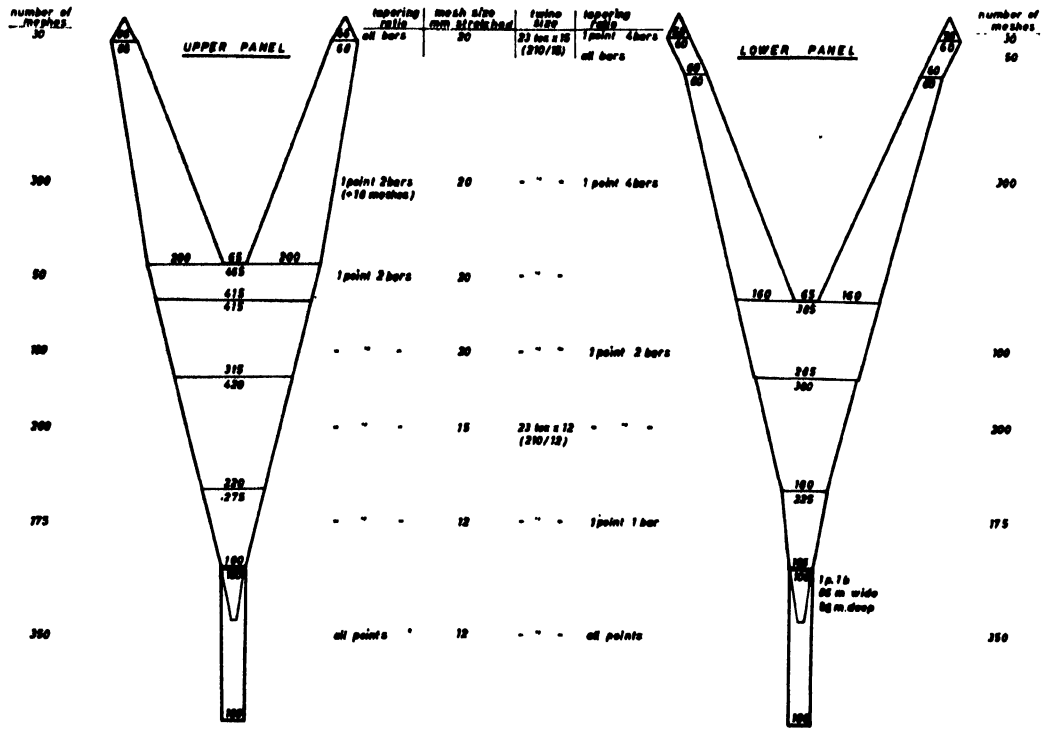


Fig 3. Structure of a freshwater two-boat bottom trawl for eel (Anguilla anguilla L)

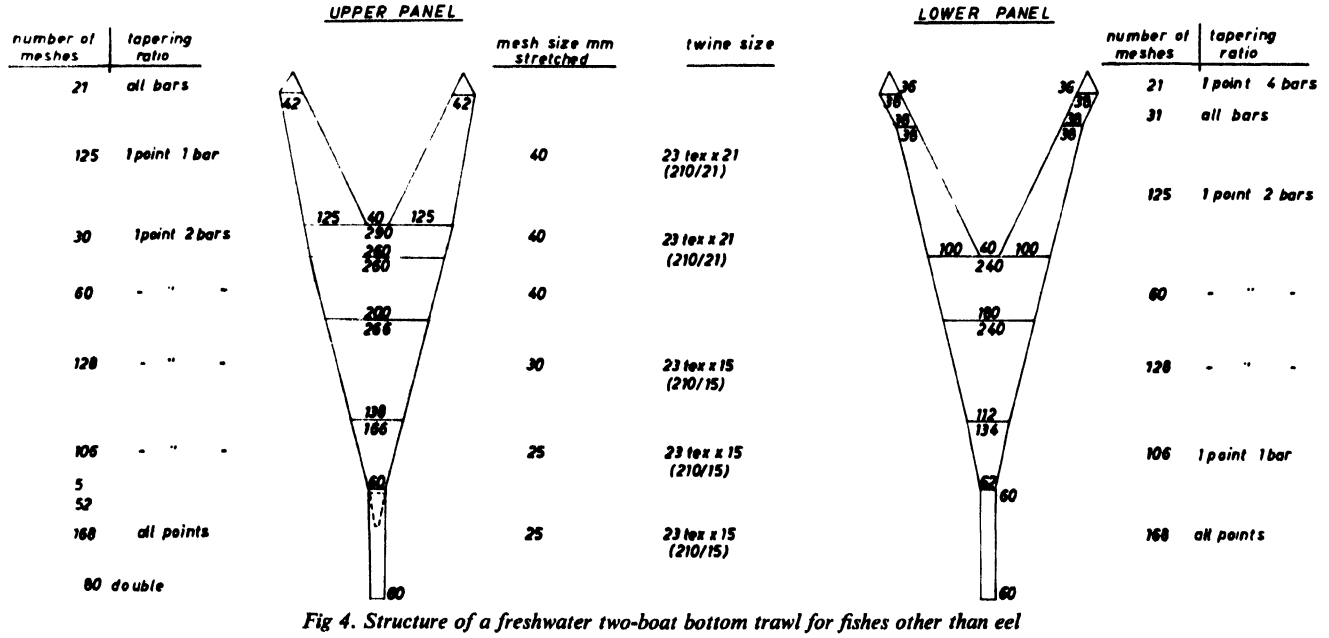


Fig 4. Structure of a freshwater two-boat bottom trawl for fishes other than eel

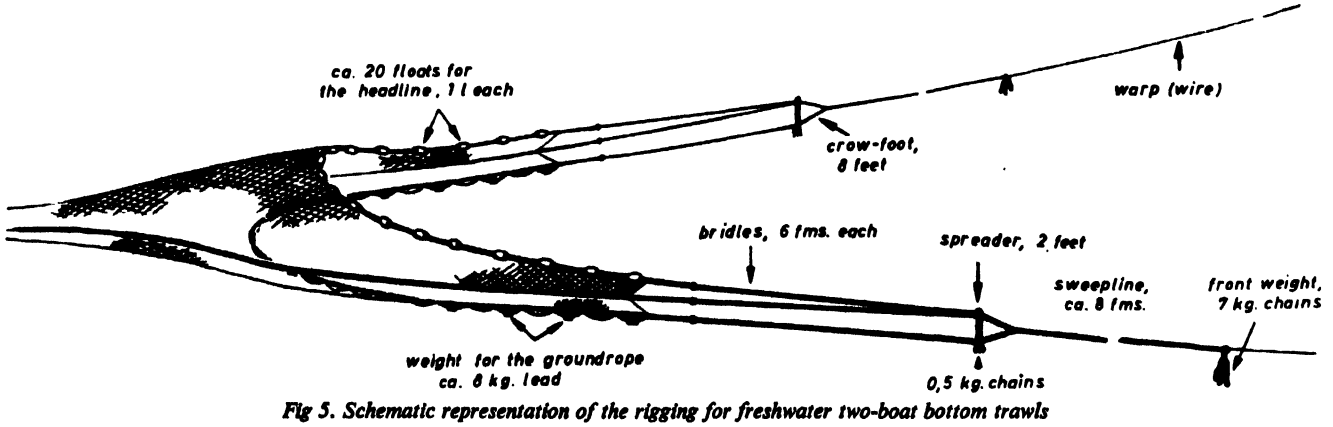


Fig 5. Schematic representation of the rigging for freshwater two-boat bottom trawls

After some unsuccessful trials with relatively small nets a suitable two-boat bottom trawl was constructed (fig 3). The excellent results obtained also caused the development of a suitable two-boat bottom trawl (fig 4) for use outside the eel season. This net differs from the eel net mainly by its larger mesh size to allow better escapement of young fish. This type of net has also proved successful. The two net types can be used effectively in deep and shallow lakes, in rivers with little currents and in artificial water reservoirs.

Rigging of the nets (figs 3 and 4) is shown in fig 5. Two vessels of 15 to 12 hp each can obtain a towing speed of 1.2 to 1.5 kn which is sufficient.

The vessel type is not so important. They can either be decked or open but sufficient space should be available for handling the gear during shooting and hauling—so the boats should be at least 6 or better 10 m long (fig 6).

Wire towing warps with a diameter of about 3 mm, or ropes with a diameter of about 8 to 12 mm are used. For wire warps small hand-operated winches are recommended. It is important also that towing warps are sufficiently long and front weights at least as heavy as those shown in fig 5. Warps with a length of 90 to 100 m are sufficient for depths down to 10 m. For water depths of 20 m the warps whould have a minimum length of 125 m. Since warps cannot be shortened by hand during towing, in cases where the water depth is constantly changing (fig 7), warp length required for the greatest depth should be used.

A special advantage of two-boat trawling in inland waters lies in the fact that only one skilled man per boat is required. In comparison with the seine net fishery this is a considerable reduction in manpower. Quick changing water depths (fig 7) and very soft ground (frequently observed in lakes) hardly affect two-boat bottom trawling. If the ground is very soft it is recommended to mount the weights of the footrope on a second line and fix this in the form of dropper chains to the footrope (fig 5). Thus the groundrope weights reach the ground before the footrope touches it. In this way the footrope does not tend to dig into the ground.

Shooting of the freshwater two-boat trawl is done in the same manner as described at sea. When hauling, some modifications are necessary due to lack of mechanically operated winches and the one-man crew per boat. Before hauling the boats must stop. Then they are turned into the direction of the gear and head for the net at slow speed. The slack towing warp is then taken aboard by hand. Following this, the bridle is passed from one

Fig 6. Different types of boats suitable for freshwater two-boat bottom trawling

Fig 7. Echo recordings during a tow with a freshwater two-boat bottom trawl in varying water depths

boat to the other and the one man goes aboard the other boat to help.

This two-boat bottom trawl fishery should be of great interest for freshwater and coastal fisheries of developing countries, e.g. of Africa, as a more efficient method. Expenses would be relatively low as only the fishing gear would have to be procured. Already existing larger pirogues (canoes) could without much difficulty serve as towing boats, as they are in many cases already equipped with outboard motors of sufficient power.

This two-boat trawling could also have a favourable effect on development of industrial fishery.

Where technical possibilities exist, one could also combine the two-boat bottom trawl fishery with the electro-fishery. This has been done on a large scale in the freshwater fishery of East Germany and Poland.

Two-boat midwater trawling

This fishery was developed in the late fourties in Denmark and was soon adopted by many other countries. This occurred in conjunction with the introduction of efficient fish finding echo sounders without which a pelagic fishery is not feasible. Two-boat midwater trawling was for many years done exclusively by well manoeuvrable cutters owing to navigational difficulties connected with shooting and hauling. Only towards 1960/61 was this method adopted by medium size sidetrawlers.

Two-boat midwater trawling with bigger boats

Since about 1948 German cutters have operated the pelagic two-boat trawl in the North Sea and the Baltic. This fishing method was adopted between 1950 and 1960 on herring (*Clupea harengus* L.) and sprat (*Sprattus sprattus* L.) which could be caught in great quantities. The decrease of the herring stocks and the decline of prices since 1960, lead to a great reduction in German activity.

The German cutters use the common four seam net with equal panels. It is towed in the customary way with four towing warps (two per cutter) and the towing depth is determined by the length of the towing warps and/or the towing speed. Modern means for the exact determination of the towing depth such as the netsonde are not common on German cutters as the fishery is carried out mostly in shallow water (<100 m). An efficient vertical echo sounder is indispensable. It is only since 1961 that German medium size trawlers, mostly called luggers, have worked with the two-boat midwater trawl. These vessels, constructed as combination drifter/trawlers, were designed for the herring fishery.

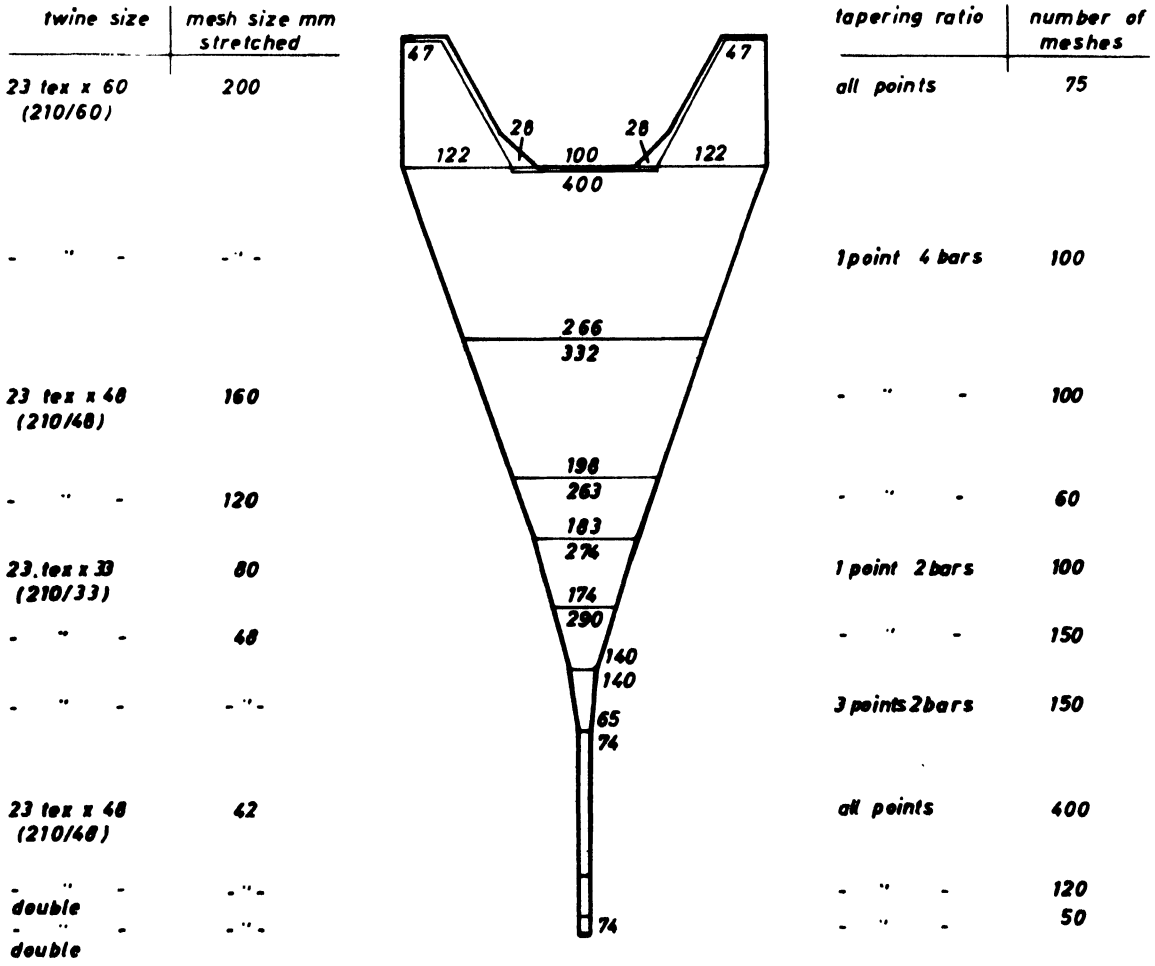


Fig 8. Structure of one of the four panels of the standard four-seam two-boat midwater trawl for German medium-size sidetrawlers (about 600 hp each)

They have a length of about 33 to 40 m with about 200 to 300 BRT and an engine power of 450 to 680 hp. These larger vessels, which specialized in herring midwater trawling, had difficulties in coping with the changing fishing conditions.

At this time a commercially suitable one-boat midwater trawl method had not yet been developed and it was attempted to adopt the two-boat trawl method of the cutters for the larger medium size trawlers. Although there was doubt as to whether these larger vessels were suitable, due particularly to their poorer manoeuvrability, it actually took only a short time to modify the two-boat method of the cutters so that it could be used with great success. This was reported at the Second Fishing Gear Congress, London, 1963 (Steinberg, R.: Two-Boat Midwater Trawling for Herring with Bigger Boats).

Important progress since then was the introduction of midwater trawls with a circumference of 1600 meshes and a mesh size of 200 mm stretched in the front part in 1963, to replace the 1400 mesh nets. In this way the average catch was increased considerably. This net (fig 8) became within a short time the standard net of the

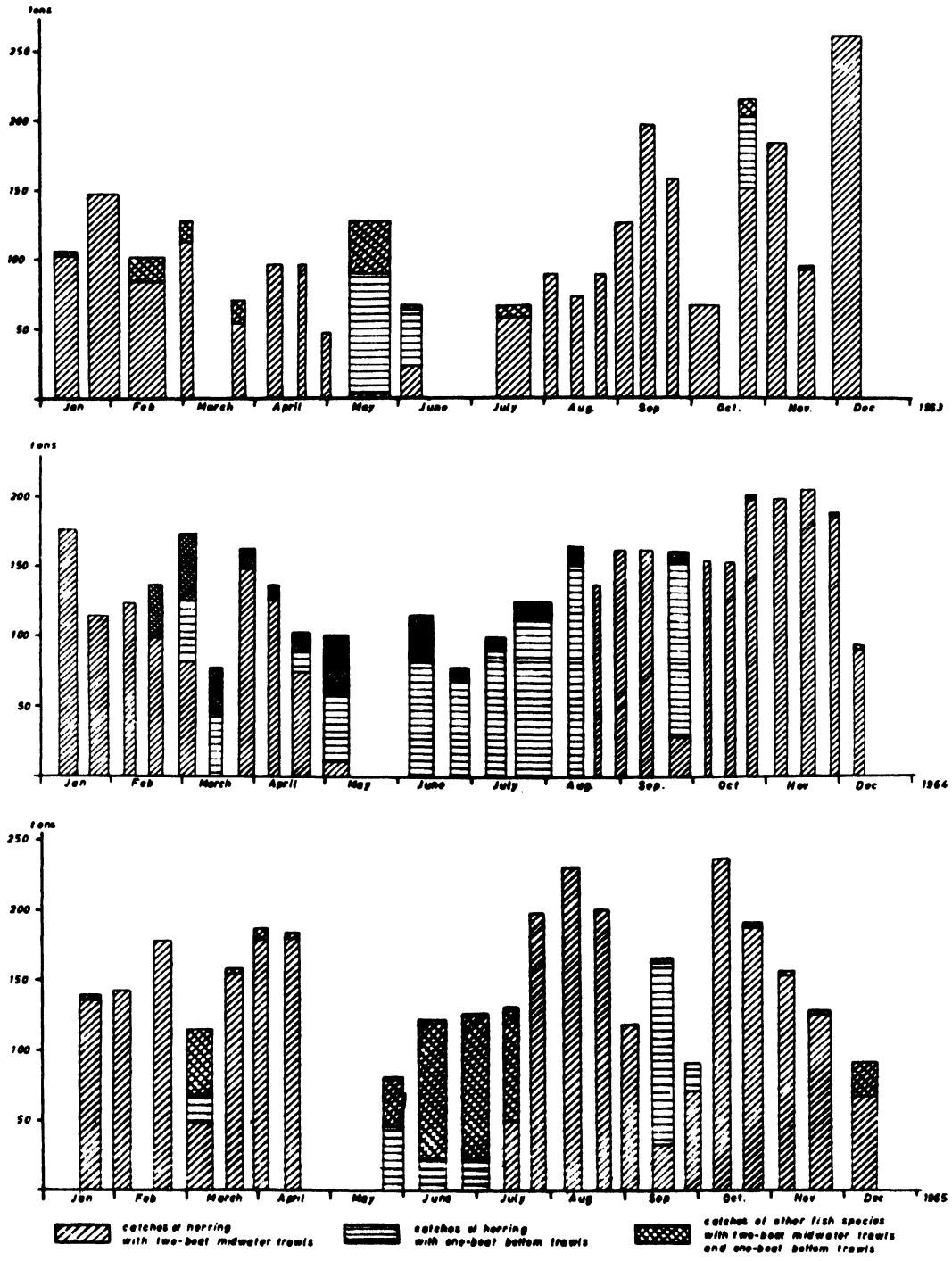


Fig 9. Catching results of two German medium-size trawlers in 1963 to 1965

German medium sized two-boat trawlers. During the last two years experiments were carried out successfully with still much larger trawls. These nets having 400 mm mesh size stretched in the front part were already in use in the Scandinavian midwater trawl fishery.

Figure 9 demonstrates the importance of two-boat midwater trawling. It shows the yields of two cooperating boats which were obtained with two-boat midwater trawls and one-boat bottom trawls during all trips between 1963 and 1965. For reasons of comparison with the two-boat midwater fishery, the total yields of the two vessels obtained with one-boat bottom trawls are shown, but only half of the total towing time is considered. The width of the rectangles in fig 9 indicates the duration of the various trips.

From fig 9 it can also be seen that in 1963 the two vessels in question produced a total of about 2,300 T of herring with the midwater trawl, and only about 180 T with the bottom trawl. The catch of other fish amounted to a total of 125 T (coal fish—*Pollachius virens*, mackerel —*Scomber scombrus*, spiny dogfish—*Squalus acanthias*, etc.), of which 75 T were taken by the two-boat midwater trawl and 50 T by one-boat bottom trawls.

In 1964 the two boats used the bottom trawl more frequently than in 1963 on account of the somewhat changed fishing situation. However, in that year considerably more herring (2,625 T) was caught by the midwater trawl than by the bottom trawl (783 T). Only in the catch of other fish species (290 T) the bottom trawl has a greater share (200 T).

In 1965, the two-boat midwater trawl was again of extreme importance. The yield of midwater trawling from both vessels amounted to about 2,680 T of herring, but only about 260 T were caught on the bottom. Of the total catch of other fish (413 T) only about 42 T were obtained by the midwater trawl.

Since 1966 the possibilities for the pelagic herring fishery on fishing grounds in the North European waters

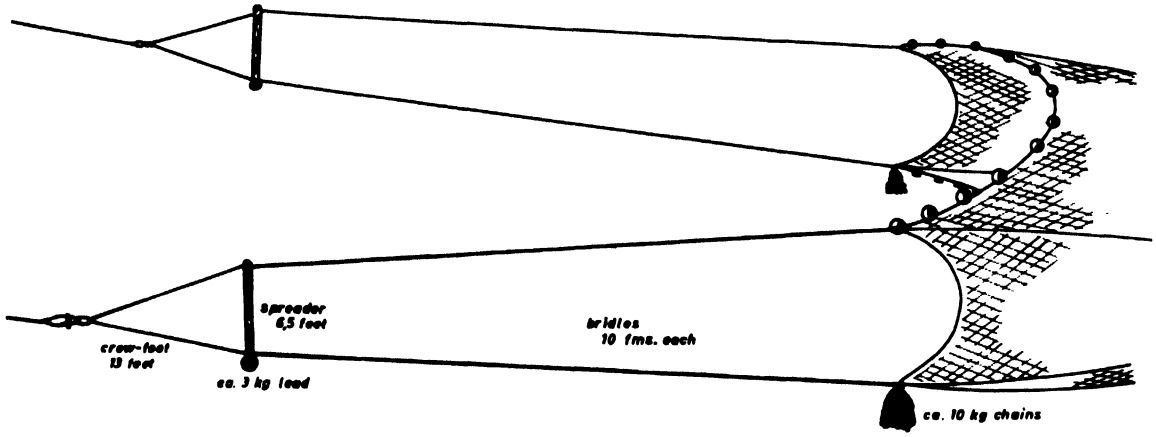


Fig 10. Schematic representation of the rigging for a freshwater two-boat midwater trawl

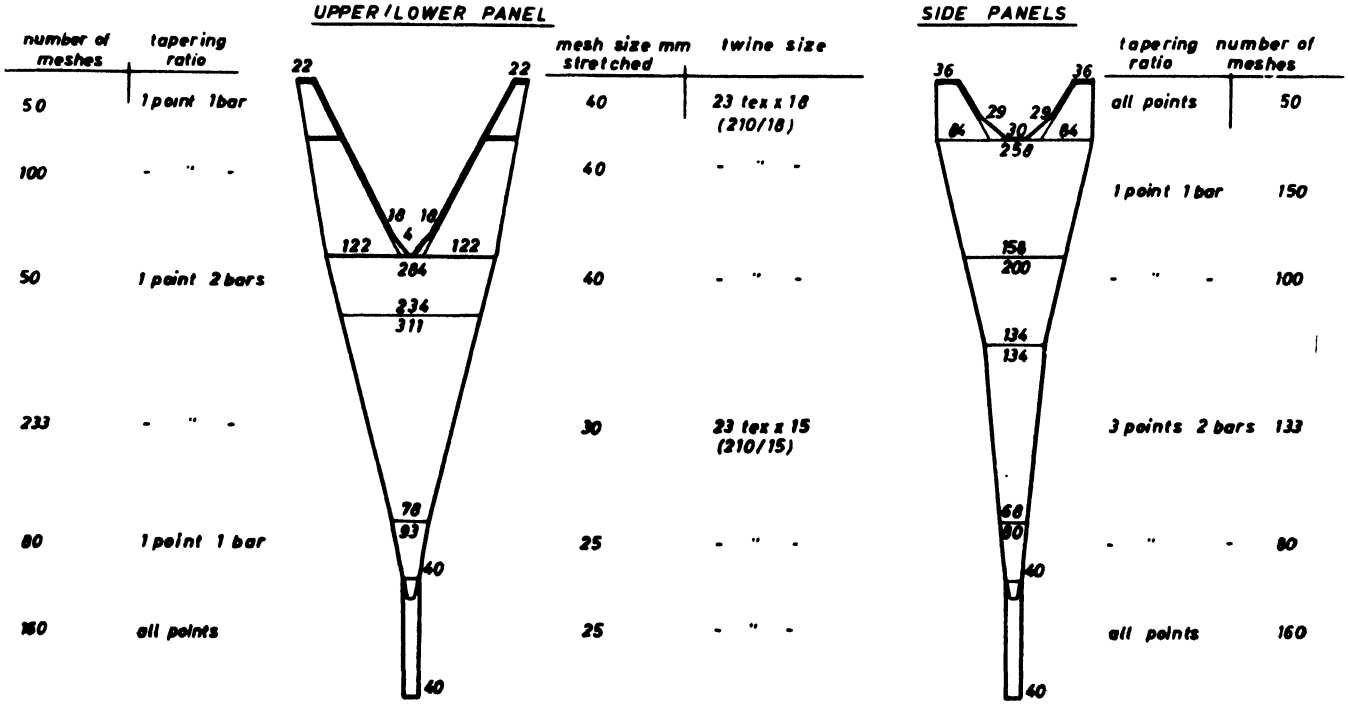


Fig 11. Structure of a freshwater two-boat midwater trawl

declined more and more. Therefore, the two-boat midwater trawl fishery gradually lost its importance. To overcome this situation, several medium-sized trawlers participated in pelagic herring trawl fishing on Georges Bank in 1968 and got good catches. Owing to distance and high cost of transport, it was not profitable to continue. So the two-boat midwater trawl method is, at present, of lesser importance in German fisheries.

Two-boat midwater trawling in freshwater

During the past two years attempts were made to use the pelagic two-boat trawl method in the local freshwater fishery, using the same gear as in deep sea fishery, but of a smaller size. At first, four towing warps were required but this proved unsatisfactory as too many people were required. Therefore, the bridle rig was modified with long spreaders (danlenos) so that only two towing warps were needed (fig 10). The opening height (about 4 m) of the net for two 20 hp boats (fig 11) was hardly changed by this modification. The optimal opening width is 12 m. As observations with a netsonde have shown, this net opening of about 50 m^2 is not always sufficient. Slowly swimming fish species such as smelt (*Osmerus eperlanus* L.) and pike (*Esox lucius* L.) can easily be caught. Fast swimming fish, however, frequently avoid the net. They can be caught in larger quantities only in turbid water at darkness.

Boats with low engine power and without powered winches do not allow the net depth to be varied during towing. This is a serious restriction. Sufficient space must also be available to make two-boat midwater trawling worthwhile. This technique can therefore only be recommended for reasonably large lakes and with suitable boats. Such conditions hardly exist in Germany, but in several developing countries two-boat midwater trawling should be seriously considered.

Notes sur le Chalutage Pélagique du Hareng et l'Utilisation du Sonar

L. Calon

Notes on herring mid-water trawling and sonar utilization

This paper groups observations made by a trawler's skipper in the field of midwater fishing and the use of sonar during trawling operations. After having precised the fish detection equipment and the fishing gear at his disposal, the author gives in particular a full description of the tactics used for herring fishing in midwater or in the vicinity of the bottom; the possibilities of sonar as an aid for trawling operations are also revised,with details in particular concerning the variations of practical range in horizontal detection, as well as the additional information that can be provided by this equipment with regard to the detection depth and the occurrence of rough bottom.

Notas sobre la pesca del arenque entre dos aguas y el empleo del sonar

En este trabajo se recogen las observaciones hechas por el capitán de un arrastrero respecto a la pesca entre dos aguas y el empleo del sonar durante el arrastre. Después de haber explicado el equipo de detección de peces y los artes de pesca de que dispone, el autor hace una descripción completa de los métodos empleados en la pesca del arenque entre dos aguas o en las proximidades del fondo. También menciona las posibilidades del sonar como auxiliar de las faenas de pesca al arrastre, y da detalles relativos a las variaciones del alcance prático de la detección horizontal, así como los datos adicionales que puede suministrar este equipo en cuanto a la profundidad de detección y la presencia de fondos sucios.

LES notes qui suivent ont pour objet de faire connaître les observations d'un capitaine de chalutier de Boulogne-sur-Mer dans le domaine de la pêche pélagique et de l'utilisation du sonar pour le chalutage. Elles résultent de plusieurs années d'utilisation, dans les conditions normales d'exploitation, d'engins de pêche très variés et d'un équipement très complet de détection et de contrôle du chalut.

Cette communication a été réalisée avec la collaboration d'Henri Thésée qui, en tant que radio du bord, remplit le plus souvent la fonction d'opérateur sonar.

Equipement de detection

Le chalutier à pêche arrière automatisé de 1750 CV de puissance motrice que je commande actuellement est équipé d'un détecteur horizontal ELAC Super-Lodar, d'un sondeur vertical ELAC, d'un netzsonde ELAC et d'un sondeur vertical ATLAS Echolot avec Fischlupe. Sur mon précédent bateau, j'ai eu aussi de très bons résultats avec un détecteur horizontal SIMRAD SB2, un sondeur vertical SIMRAD EH2, un netzsonde ATLAS et un sondeur vertical ATLAS Echolot avec Fischlupe.

Depuis plusieurs années j'ai eu l'occasion d'utiliser un grand nombre de sondeurs et de détecteurs horizontaux de différentes marques. Chaque appareil, chaque marque a des performances différentes; plus précisement, tel détecteur horizontal a un meilleur rendement au son, tel autre une meilleure sensibilité au papier. De même, un sondeur vertical peut être plus optimiste, si l'on peut dire, qu'un autre, qui, lui, a une meilleure définition des échos de fond.

D'une manière générale on peut dire que la pêche au chalut pélagique ou semi-pélagique ne peut se concevoir qu'avec des sondeurs ultra-sensibles munis du dispositif "ligne blanche", ma préférence personnelle allant plutôt au papier humide en utilisation verticale à cause de sa plus grande sensibilité. En ce qui concerne le sonar, on peut dire qu'à condition d'être employé rationnellement par un opérateur habile il constitue un complément d'équipement qui se révèle fort rentable.

Bien que le détecteur parfait n'existe pas encore, je reste tout du même surpris et enthousiasmé par les progrès réalisés en plus de vingt ans de commandement.

Chalutage pelagique du hareng

Pour la pêche du hareng on a d'abord utilisé le chalut de fond avec deux plateaux élévateurs, puis le chalut "carré" gréé comme dans le système Breidfjord, ensuite le "semi-pélagique" ou chalut de fond à grande ouverture verticale avec netzsonde, ce dernier type étant encore beaucoup employé sur les fonds de moins de 50 mètres.

Enfin, depuis plusieurs années, les chaluts pélagiques avec panneaux Süberkrüb se sont beaucoup développés. Il y a 5 ans nous en étions encore aux panneaux de 4 mètres carrés avec chalut de 1400 mailles de 20 cm (mesure maille étirée) et poids de 400 kg de chaque côté, ce qui nous donnait 14 mètres d'ouverture verticale. Nous en sommes maintenant aux panneaux de 8 mètres carrés avec chalut de 710 mailles de 56 cm et poids de 800 kg de chaque côté, ce qui nous procure une ouverture verticale de 20 mètres.

Tactique de pêche

Dans la pêche au hareng deux cas peuvent être distingués:

Le hareng en taches très concentrées—Le hareng avant de frayer est très vif et ses moyens de défense sont la montée verticale rapide ou l'écartement latéral lors du passage du chalut.

Le hareng en taches diffuses ou d'assez grande étendue—Il s'agit par exemple de la détection de nuit qui est généralement plus facile à pêcher.

Dans la pratique, le captaine choisit la zone à prospecter d'après sa propre connaissance des frayères et des régions où, suivant la saison, peut se trouver le hareng. Il tient compte, également, dans son choix de la synthèse des informations reçues par radio.

La prospection s'effectue alors de la manière suivante: en arrivant sur le lieu de pêche le chalutier patrouille à grande vitesse (sonar en service) pour explorer la plus grande surface possible dans un minimum de temps. Dès qu'un écho est perçu le bateau va le reconnaître à moins qu'il n'y ait aucun doute sur sa nature. Dans tous les cas, la mise en pêche ne se fait qu'après avoir trouvé un objectif convenable.

On peut ainsi rencontrer: soit une détection très collée sur le fond, mais de faible élévation verticale, qui se révèlera productive de nuit, soit un "brouillard", soit des taches diffuses, soit enfin des "poteaux", terme qui désigne des bancs à grande dimension verticale dans lesquels le poisson est en général très dense.

Pour la détection plaquée sur le fond ou pour le "brouillard" l'efficacité du sonar sera généralement nulle ou extrêmement faible à moins que l'on ne puise utiliser une particularité du relief du fond en guise de repère.

Pour une tache diffuse ou dispersée, la portée sera réduite très sensiblement (fig 1).

Pour le détection en "poteaux", suivant la densité du poisson et les qualités des eaux au moment donné, il est possible de repérer les concentrations de harengs à des distances de 1200 mètres en moyenne (fig 2), cette distance pouvant être parfois doublée.

Mais il reste toujours la difficulté provenant du déplacement rapide des bancs. Après avoir repéré le poisson et si possible apprécié la valeur de la tache par un passage à la verticale, on se place à bonne distance pour mettre le chalut à l'eau, tout en gardant le contact au sonar. Le filage s'effectue en direction de la tache, en corrigeant le cap selon les indications du sonar pour compenser le déplacement du poisson vers la droite ou la gauche de façon à arriver sur la tache le filet bien droit. Il faut s'efforcer d'amener encore une fois le bateau à la verticale de la tache pour contrôler sa hauteur. Il s'agit alors de manoeuvrer pour amener le chalut dans la détection.

Avec des panneaux Süberkrüb de 8 mètres carrés, des chaluts de 1600 ou 2000 mailles de 20 cm et des poids de 800 kg de chaque côte, on file environ trois fois la profondeur d'immersion de la tache.

Le meilleur rendement est obtenu lorsque le poisson entre sur toute la hauteur d'ouverture du chalut en

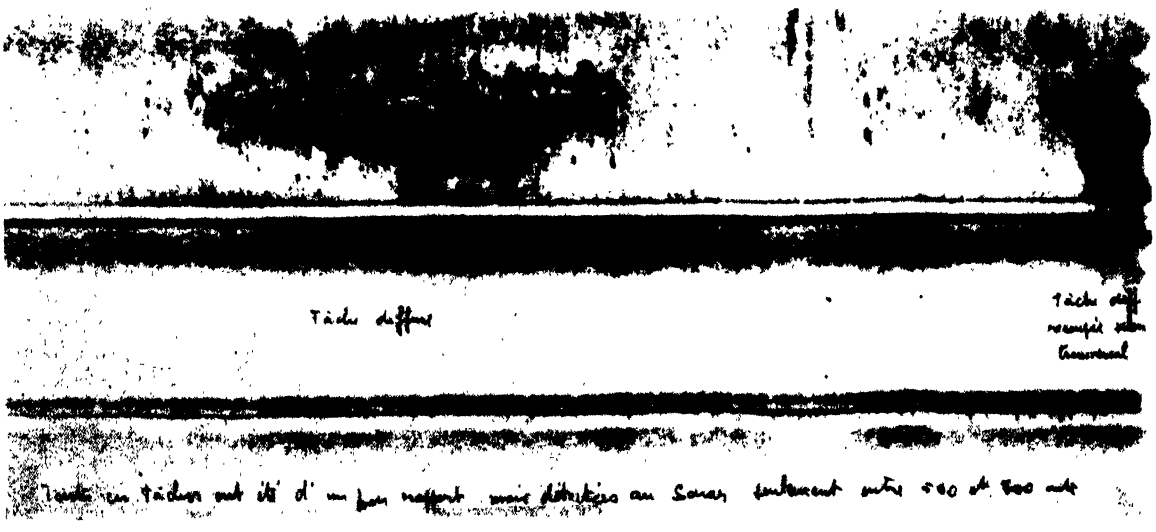


Fig 1. Tache diffuse de hareng de détection médiocre au sonar

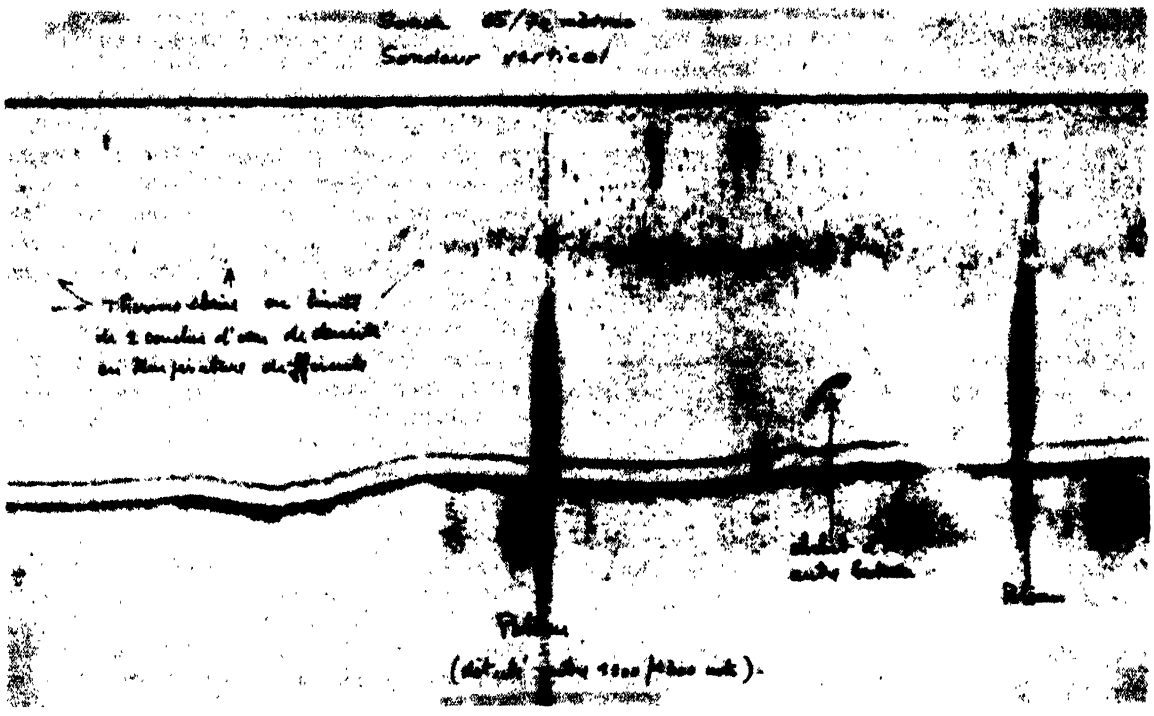


Fig 2. Tache compacte de hareng en "poteau" de très bonne détection au sonar. La bande floue de détection à un niveau à peu prés constant traduit la présence d'une thermocline marquée

donnant la même figuration graphique au netzsonde qu'au sondeur vertical.

Depuis deux ans, il est apparu que le problème du refoulement de l'eau à l'entrée du filet était très important; nous avons donc approfondi l'engueulure de nos chaluts, tant semi-pélagiques que pélagiques, pour éviter ou tout au moins diminuer le refoulement de l'eau qui aide le poisson à se dégager du chalut. En effet, il était très fréquent auparavant d'observer plus de détection au netzsonde qu'au sondeur vertical; ceci provenait du fait que le hareng n'allait pas au fond du chalut mais, aidé en quelque sorte par le refoulement de l'eau, se maintenait à l'entrée du chalut sous le netzsonde.

Il peut arriver aussi quand le poisson est très vif et nerveux que les taches ne rentrent pas dans le filet, on s'aperçoit alors grâce au sonar que la détection défile sur

Fig 3. Enregistrement au sonar d'un banc de hareng détecté à partir de 2,300 mètres. Après avoir maintenu le contact en se rapprochant, par une rotation du projection vers l'arrière on peut apercevoir le banc qui s'éloigne du bateau en passant au niveau du chalut repérable par sa distance constante

tribord ou babord malgré les abattées et ceci pendant des heures, voire des journées entières, surtout lorsque les eaux sont claires et avec des marées de morte-eau.

Pour ce qui est de l'emploi du sonar, j'ai constaté que sur certains fonds "secs", de bonne résonance sonore, le poisson était affolé par le bruit du faisceau d'ultrasons. Profitant de cette particularité, il nous arrive lorsque le poisson est très vif de chasser les concentrations de harengs vers l'arrière à l'aide du sonar de façon à le rabattre vers le chalut (fig 3). D'autres fois, lorsque le hareng est trop nerveux et affolé par le sonar ou les bruits d'hélice, il nous arrive en pêcherie de stopper l'émission sonar pour tranquiliser le poisson et le rendre plus "pêchant".

Au point de vue de la détection en général l'observation montre que l'écho reçu n'est pas toujours en rapport avec la densité réelle du banc de poisson, et il nous arrive bien souvent d'être surpris par les résultats obtenus: tantôt la pêche est très forte sur des détections peu importantes, tantôt des détections massives sont peu productives. Il semble que ces différences d'aspect de la détection proviennent surtout du comportement du poisson, de sa nage plus ou moins active en bancs plus ou moins serrés selon son état physiologique (en période de reproduction notamment).

Au sujet de la vitesse de chalutage, deux points sont à considérer:

En chalutage pélagique—Pour la pêche entre deux eaux, la vitesse de chalutage est fonction du but visé et elle varie selon la hauteur des bancs à capturer. C'est en agissant sur la vitesse que nous faisons varier l'altitude du chalut par rapport au fond, mais il faut tenir compte du fait que, pour une traîne à un niveau donné, il est plus aisé d'accroître la vitesse si les poids ont été augmentés en conséquence. En définitive, plus les poids sont lourds, plus on peut augmenter la vitesse tout en conservant une certaine stabilité du chalut. Des poids trop légers rendent le train de pêche trop volage et trop sensible aux moindres variations d'allure, il devient alors impossible de le maintenir à une altitude donnée.

En chalutage démersal—Il faut obtenir une traction régulière quels que soient le vent et le courant sans tenir compte de la vitesse au loch. Il faut souligner à cet égard l'avantage apporté par l'appareil indicateur de traction dont on arrive maintenant à obtenir un résultat pratiquement optimum en ce qui concerne la régularité de la traîne (fig 4).

Le principe de cet appareil est connu. Des indicateurs donnent la pression exercée sur un vérin relié aux freins de treuil; à l'aide de courbes définies en fonction notamment du diamètre d'enroulement des tambours du treuil, l'on obtient la valeur réelle de la traction exercée sur les funes. C'est cette traction réelle qu'il faut tâcher de maintenir quelle que soit l'allure afin d'obtenir une régularité satisfaisante du rendement du chalut dans des conditions déterminées.

Utilisation du sonar

En règle générale, les meilleurs résultats au point de vue détection horizontale sont obtenus sur les taches en

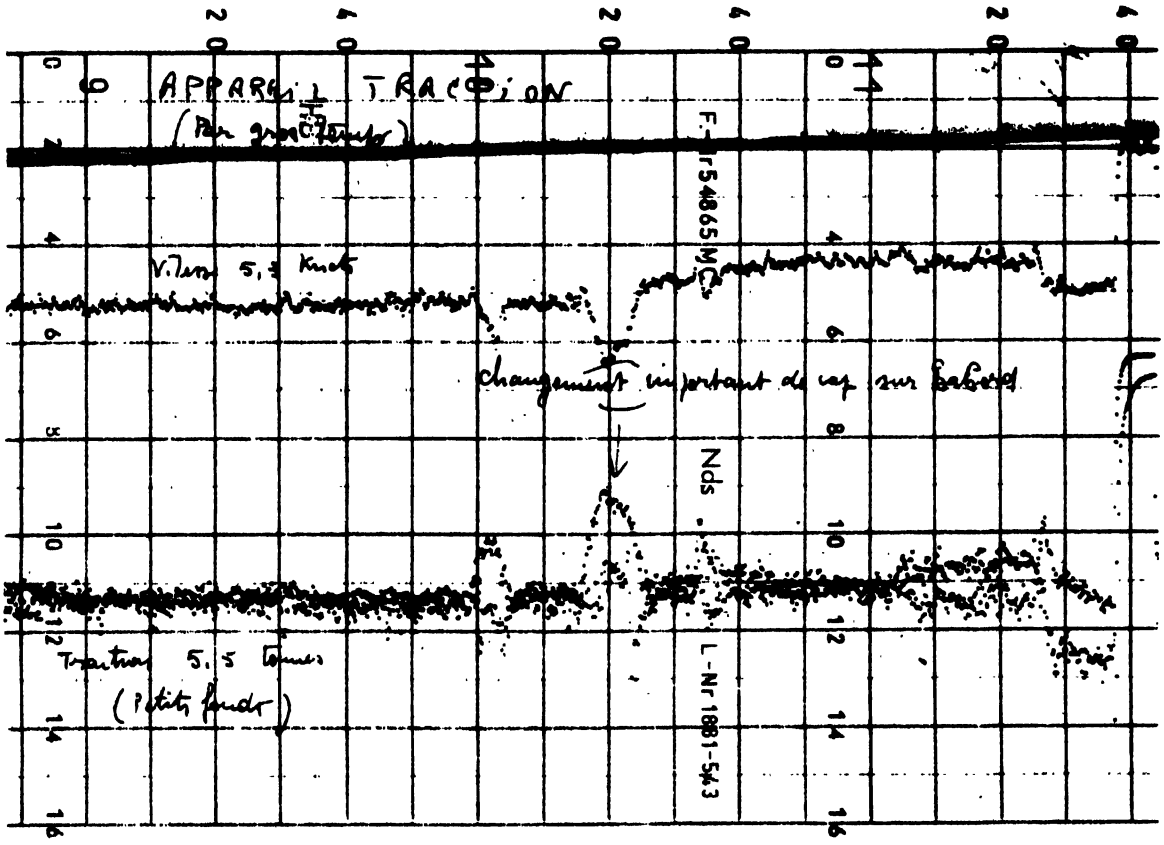


Fig 4. Enregistrement d'un appareil de mesure de la traction sur les funes. Dans la pratique on distingue les valeurs des funes de babord et de tribord au moyen d'encres de couleurs différentes. La vitesse au loch est également enregistrée simultanément

forme de "poteaux" (rappelons qu'on désigne ainsi les taches qui affectent la forme d'un menhir soit à partir du fond, soit entre deux eaux, avec des bords nets sans excroissances). Les taches diffuses, même énormes, les "brouillards", même épais, donnent des résultats bien moins intéressants et souvent médiocres quant à la distance de détection horizontale. Ceci bien entendu dans les conditions les meilleures de propagation et d'utilisation (qualités physiques des eaux, conditions météorologiques, densité de la pêcherie, etc).

Toujours dans le domaine des considérations générales, nous développerons quelques points particulièrement importants.

En premier lieu il faut citer les qualités physiques des eaux. Il y a des zones où, selon les saisons, ou parfois à longueur d'année (par exemple en Mer du Nord, au Sud de la Norvège, les atterrages Ouest du Skagerrak), les conditions de propagation des ultrasons sont tellement mauvaises et aléatoires que les résultats obtenus ne peuvent pratiquement pas être pris en considération par des chalutiers, alors que les senneurs qui travaillent dans les eaux superficielles de cette même région peuvent encore tirer profit de la détection horizontale. Ceci est dû soit à la présence d'une thermo-cline (variation brusque de température à une certaine profondeur) soit à des couches d'eaux de densité et salinité différentes qui infléchissent les faisceaux d'ultra-sons vers le haut ou le bas. Tous ces phénomènes sont d'autant plus sensibles que l'on travaille dans des profondeurs plus grandes (100, 150, 200 mètres et plus). Dans les petits fonds, inférieurs à 90/100 mètres, dans les zones que nous fréquentons, ces difficultés sont en général amoindries, mais il s'en présente d'autres.

En effet dans les petits fonds, on peut être gêné par des échos parasites provenant de la réverbération du faisceau ou des lobes latéraux sur un fond plus ou moins dur ou irrégulier (fig 5). D'autre part, toujours par faible profondeur, si le nombre des bateaux chassant dans le même secteur est élevé, le faisceau horizontal fournira des échos sur les sillages ou sur les coques. Dans ce cas-là, l'expérience et l'entrainement de l'opérateur lui permettent de sélectionner les échos reçus. Mais, si les bateaux sont très nombreux et travaillent sur une très petite zone dans des petits fonds, les remous créés par les sillages finissent par modifier les conditions de propagation au sonar dans des proportions extrêmement importantes. Toutefois, il nous faut signaler que, pour les chalutiers, les inconvénients dus à une grande concentration de bateaux sur une pêcheris sont très fortement atténués dans les fonds supérieurs à 100/150 mètres du fait que la détection s'opère alors dans la partie inférieure de la couche d'eau. Signalons en outre pour mémoire les interférences provoquées par les autres sonars, mais ceci ne constitue un inconvénient majeur.

De mauvaises conditions météorologiques sont aussi une source de perturbation dans l'emploi du sonar; elles peuvent provoquer une diminution importante de la portée en particulier par faible profondeur.

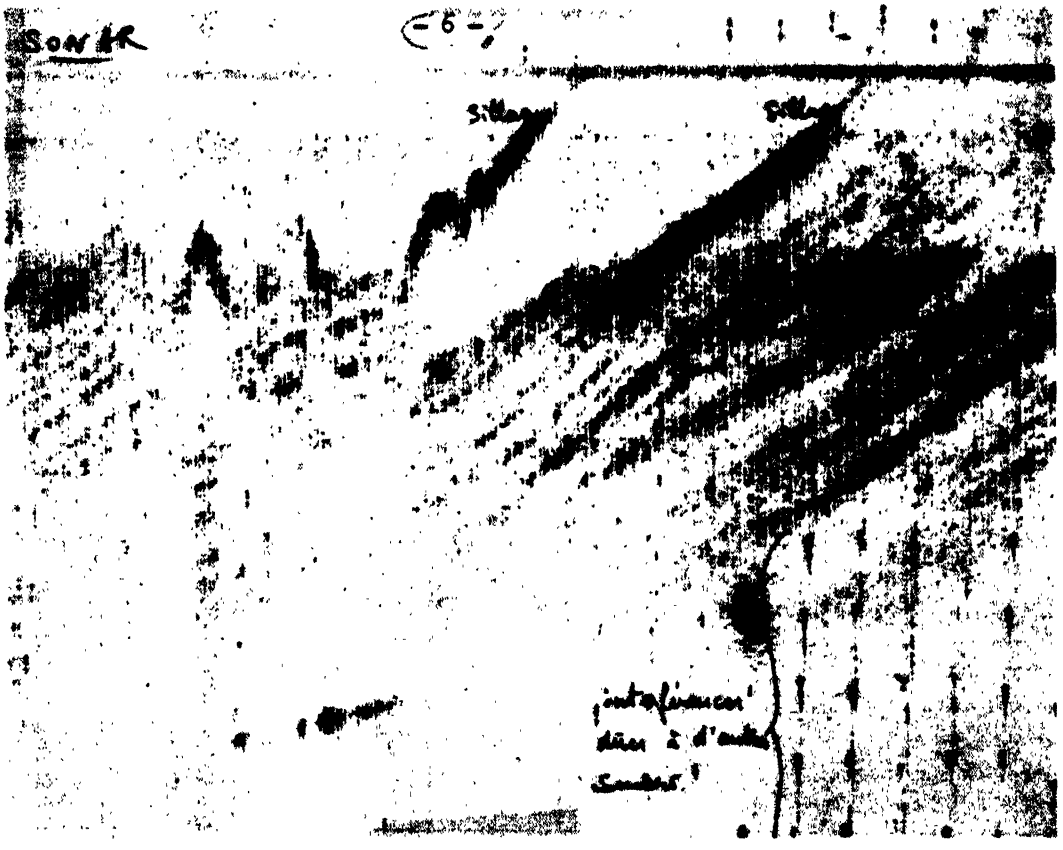


Fig 5. Quelques échos parasites au sonar; sillages de bateaux, variations de la nature du fond, interférences avec les émissions des sonars des autres navires

En définitive, la distance pratique de détection horizontale se situe donc actuellement entre 1000 et 1500 mètres dans de bonnes conditions de travail, cette distance pouvant être parfois doublée dans des conditions exceptionnellement favorables. A l'inverse dans de mauvaises conditions de propagation comme celles mentionnées plus haut la portée pratique peut tomber à 300 ou 200 mètres ou même devenir pratiquement nulle.

Détermination du niveau de la détection

Il faut ensuite faire la distinction entre les taches au voisinage du fond et les taches entre deux eaux; la détection en surface n'intéresse en effet les chalutiers en opération de pêche qu'à titre d'information éventuelle.

Lorsque l'on travaille par petits fonds (par exemple entre 40 et 70 mètres) on peut dire que les taches partant du fond et celles commençant à une faible distance du fond donnent des échos sonar qui ne permettent pas de les différencier; dans ce cas, seul un passage à la verticale de la tache permet de connaître cet élément important qu'est la position du banc par rapport au fond. Si la tache se trouve en surface ou encore dans la moitié ou le tiers supérieur de la tranche d'eau considérée on arrive néanmoins à s'en apercevoir avec l'expérience.

Dans des fonds plus importants (80 à 150 mètres), le problème n'est pas tout à fait le même. On peut tout de suite éliminer les échos reçus de taches situées dans le tiers supérieur de la tranche d'eau considérée sans avoir besoin d'aller les reconnaître par un passage à la verticale. Pour les taches situées dans le tiers intermédiaire de la tranche d'eau, elles sont plus facilement localisables dans le plan vertical que par petits fonds, mais de toute façon il faut effectuer un passage à la verticale. Quant aux bancs situés au fond ou tout près du fond, donc dans le tiers inférieur de la tranche d'eau, on peut arriver à les différencier mais sans pouvoir dire avec certitude si elles touchent au fond ou si elles en sont à une très faible distance. Par conséquent, là encore, un passage à la verticale s'impose.

Les mêmes observations sont valables pour des fonds supérieurs à 150/200 mètres, toutefois il convient alors de faire quelques remarques.

Etant donné la faible ouverture angulaire du faisceau d'ultra-sons dans le plan vertical, par faible profondeur toute la tranche d'eau du fond à la surface est pratiquement explorée. Dans les fonds moyens, les zones non explorées dans le plan vertical par le faisceau d'ultra-sons augmentent avec la sonde pour devenir très importantes dans les grands fonds, d'où la nécessité de jouer sur le site à donner au faisceau selon le niveau que l'on veut explorer. Cela permet d'éliminer les taches trop hautes qui ne seraient pas intéressantes pour des chalutiers (fig 6).

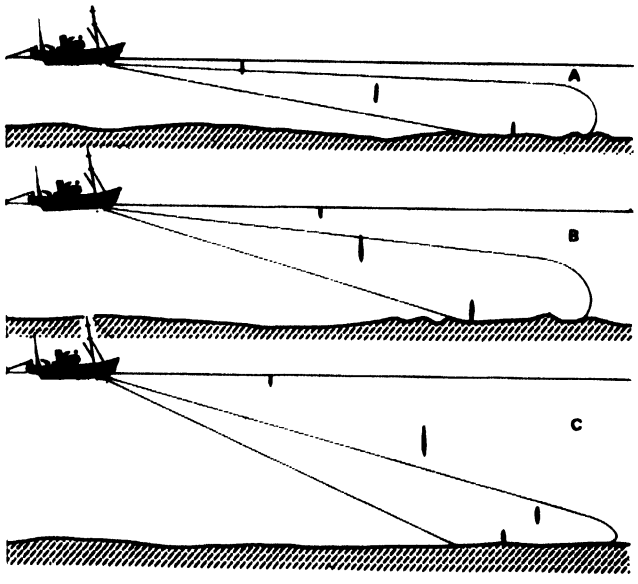


Fig 6. Détermination du niveau de la détection. Difficile ou impossible par faibles ou moyennes profondeurs (a et b), elle devient possible par grande profondeur en agissant sur le site du faisceau (c)

Repérage de mauvais fonds

Nous avons déjà parlé des échos provenant de la réflexion du faisceau d'ultra-sons et de ses lobes secondaires sur le fond, échos qui peuvent être plus ou moins marqués selon la nature de ce dernier. Cette particularité permet de détecter à l'avance un changement dans le type de fond même en l'absence de tout relief.

On détecte également les modifications dans le profil du fond (ridens, buttes, têtes de roche, épaves, etc.). Eventuellement, pour une meilleure localisation du poisson, une anomalie du fond peut être utilisée comme une sorte d'amer.

Bien entendu, la détection des accidents du fond permet d'autre part de manoeuvrer pour éviter un danger pour le chalut. Il arrive que l'on utilise le sonar uniquement dans ce but lorsque la position d'obstructions sur le fond est mal déterminée.

Cette utilisation du sonar est beaucoup moins courante, car l'on se sert d'habitude des sondeurs verticaux pour cela, elle n'est pas cependant à écarter à priori. Il convient néanmoins de remarquer que, dans le cas d'un accore ou d'une pente importante et élevée, il vaut mieux ne pas utiliser le sonar à contre-pente, car l'écho du fond devient alors prépondérant au détriment de tous les autres (même des obstructions éventuelles). Il faut donc prospecter uniquement dans le sens de la pente ou dans le sens des isobathes.

Las Experiencias en la Pesca con Redes de Media Agua en el Mar Argentino

S. L. Okonski, L. W. Martini

Experiences in midwater trawling off Argentina

With the research vessel *Cruz del Sur* of the Fisheries Development Project in Argentina (Argentinian Government/FAO UNDP) experimental and exploratory fishing is being conducted with both purse seines (anchoíta, bonito) and midwater trawls (anchoíta). This paper deals with the midwater trawling trials under various environmental conditions, towing near the surface, in midwater and near the bottom. Fishing conditions, gear design and operational techniques are described and illustrated with echograms.

Essais de chalutage pelagique au large de l'Argentine

Des pêches expérimentales et exploratoires sont réalisées actuellement par le navire de recherche *Cruz del Sur* du Projet pour le développement des pêches en Argentine (Gouvernement Argentin/FAO UNDP) avec à la fois des seines coulissantes (anchoita, bonite) et des chaluts pélagiques (anchoita). Le présent document concerne les essais de chalutage pélagique effectués près de la surface entre deux eaux et au voisinage du fond, dans des conditions de milieu variées. Les conditions de pêche, la conception de l'engin et les techniques opérationnelles sont décrites, avec des enregistrements ultra-sonores en exemples.

LAS primeras experiencias con redes de media agua en la República Argentina, commenzaron en los años 1967 y 1968, durante la época en que la anchoíta desova frente a las costas del puerto de Mar del Plata, concentrándose en cardúmenes muy densos y extensos, en los meses de septiembre y octubre.

La red y los portones utilizados se adaptaron de los modelos y portones "Dual Fin" y "Phanton" representados en el libro "Modern Fishing Gear 1", p. 341.

Los resultados obtenidos con este tipo de red no tuvieron el éxito esperado. En algunas ocasiones las capturas por hora de arrastre fueron de hasta 10–12 toneladas, pero muchas veces se fracasaba y no se capturaba nada. Los principales inconvenientes fueron:

1. Los barcos comerciales no poseen ecosonda y transductor para colocar en la boca de la red, de ahí que se desconociera la abertura vertical de la boca de la red y la posición de la red entre la superficie del agua y el fondo del mar.
2. Como consecuencia de lo anterior, cuando se lanzaba la red fuera de las 10 brazas de profundidad, las capturas eran nulas.
3. Los capitanes de pesca desconocían el método para calcular la abertura horizontal de los portones.
4. Los capitanes de pesca y tripulantes desconocían la forma de aparejar los portones y la red, y su manipulación.

Con el arribo al país del buque de investigaciones pesqueras "Cruz del Sur" y del Technólogo en artes de pesca de la FAO, el Proyecto de Desarrollo Pesquero Argentino se abocó a la tarea de intensificar las experiencias con redes de media agua para la captura de anchoíta

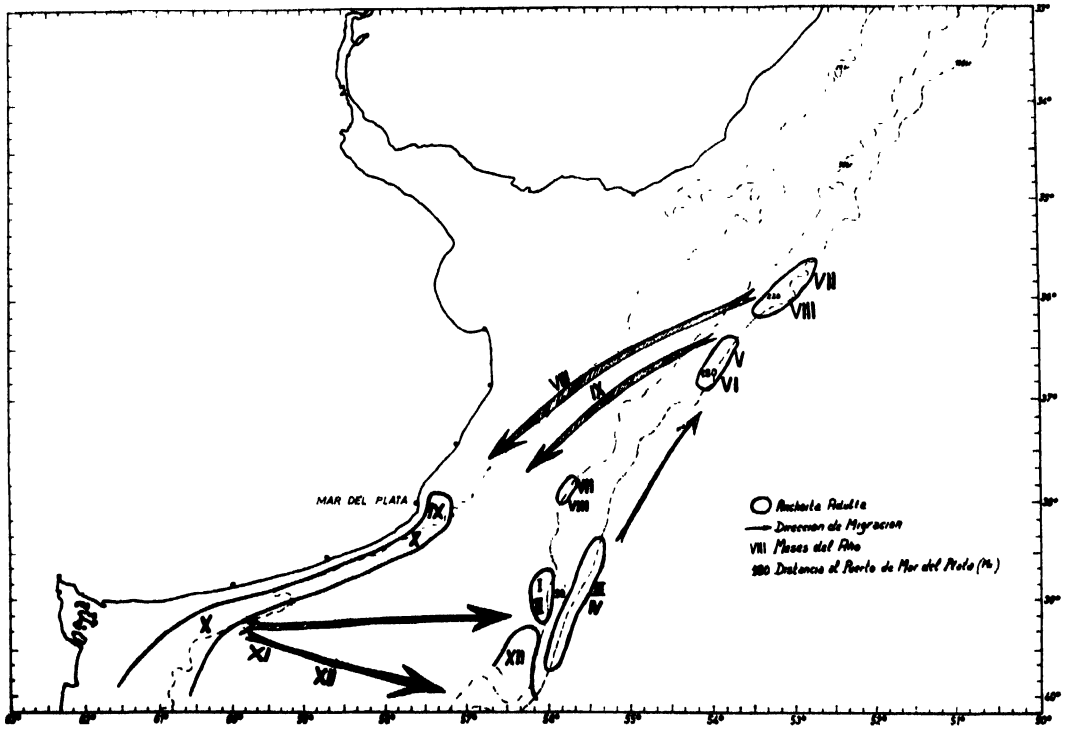


Fig 1. Distribución de anchoíta en 1969

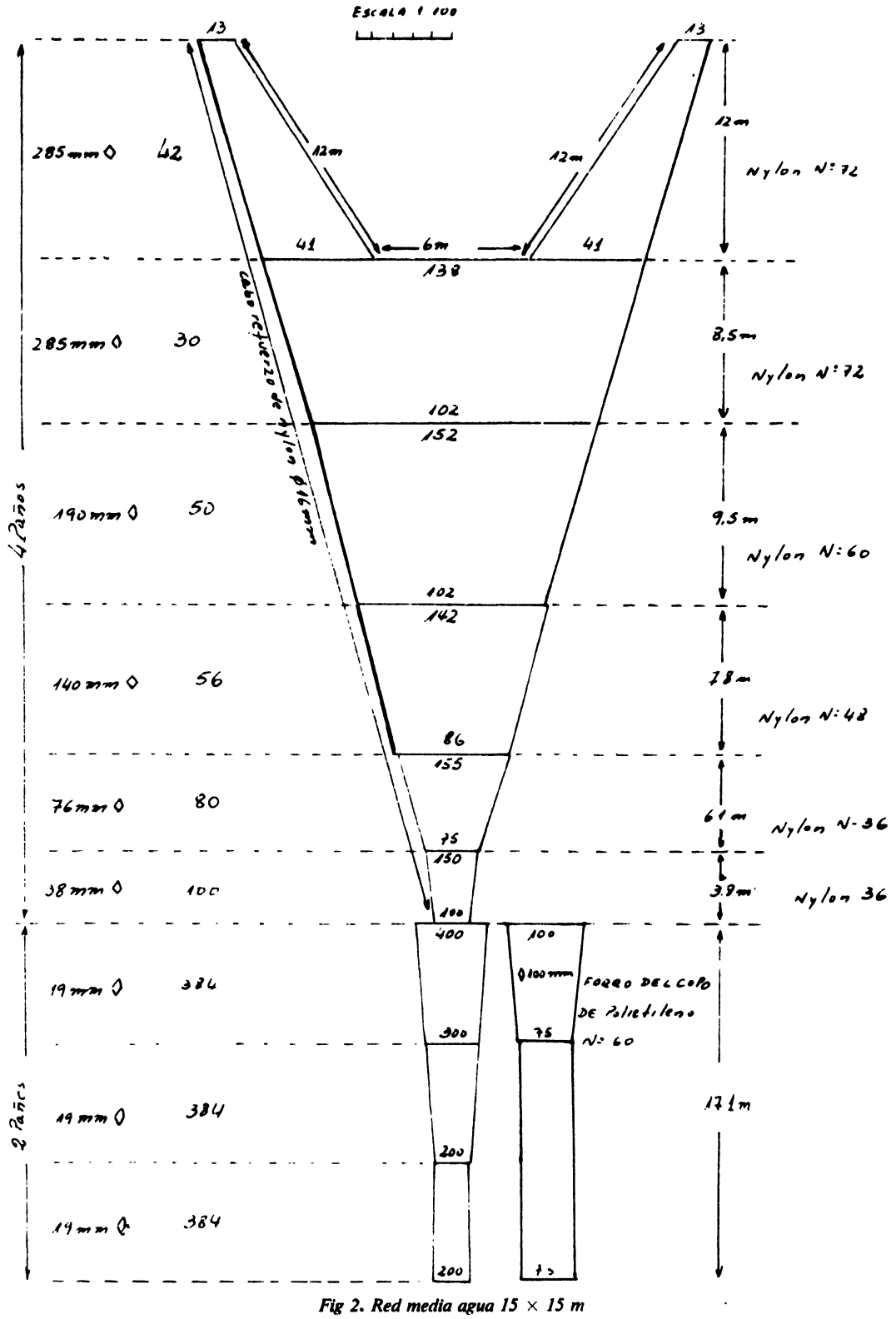
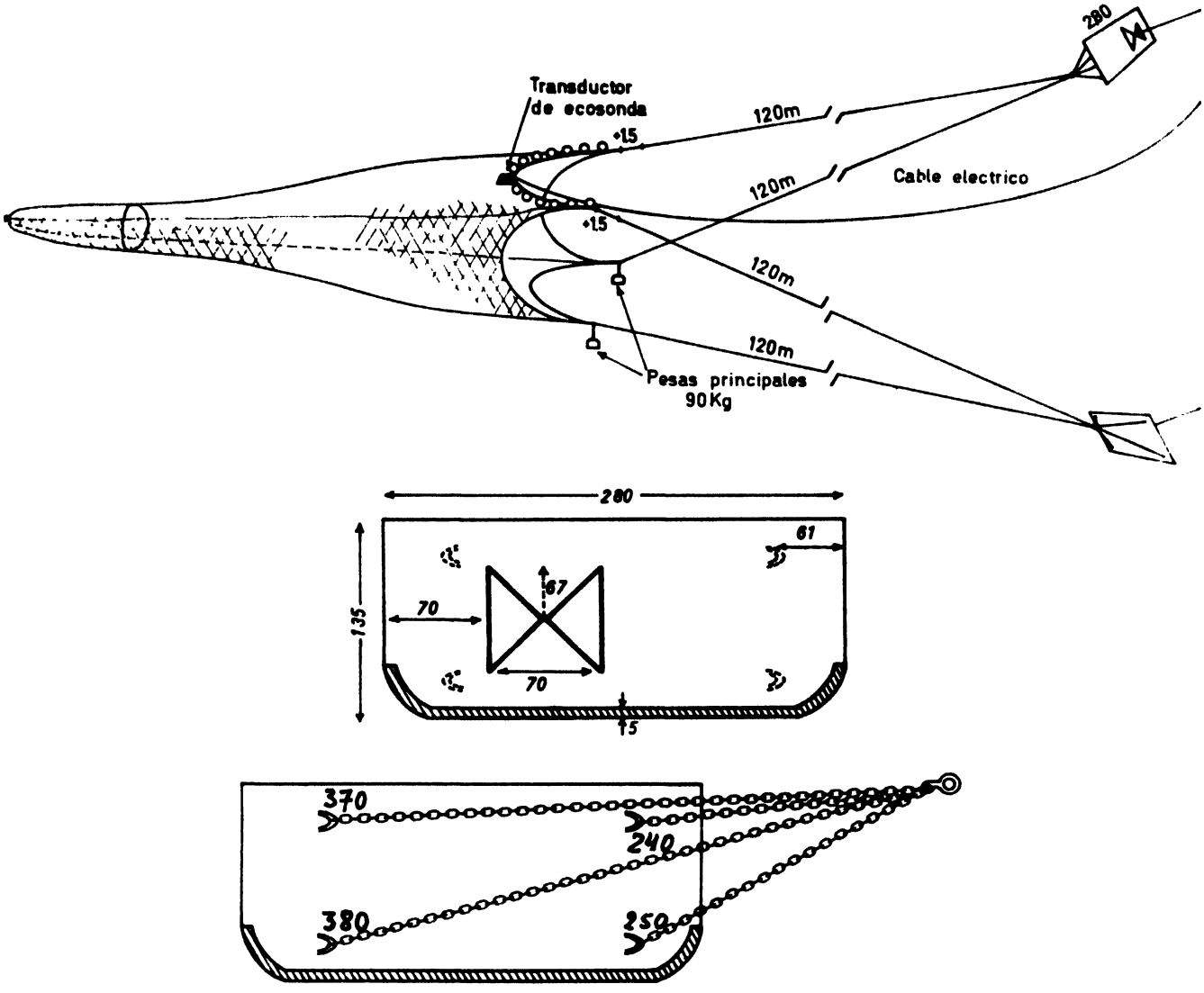


Fig 2. Red media agua 15 × 15 m

y estudiar, al mismo tiempo, el comportamiento de esta especie y sus reacciones a este tipo de aparejo. En el transcurso del año 1969, excepto durante el mes de febrero, el "Cruz del Sur" siguió los desplazamientos de la anchoíta en la plataforma bonaerense argentina, los que se muestran en la fig 1, la cual indica también la distancia aproximada de las concentraciones al puerto de Mar del Plata, donde está basado el 95 por ciento de la flota pesquera argentina.

Experiencias con la red de media agua en el buque de investigaciones pesqueras "Cruz del Sur"

El Technólogo en artes de pesca del Proyecto diseñó un prototipo de red de media agua adaptable para el "Cruz



Pie de gallos para adaptar el porton para trabajo en media agua.

Fig 3. Aparejo y portón utilizados por el Cruz del Sur

del Sur" (eslora 32,60 m; potencia motor 680 hp), calculando la abertura de la boca de la red en 15 × 15 m respectivamente en sentido horizontal y vertical, cuando la red estira 50 por ciento de las relingas superior e inferior, como se muestra en la fig 2. El equipo se aparejó tal cual se muestra en la fig 3.

Las experiencias con este tipo de red comenzaron en febrero de 1969. Los portones utilizados fueron los normales de pesca comercial con red de arrastre por el fondo: rectangulares, de 3,8 m² de superficie y 550 kg de peso en el aire. Se les adaptó para pesca de media agua, utilizando 4 pies de gallo en cada portón, de longitudes tales que proveyeran un ángulo de ataque de 40° en media agua, y de 45° para trabajar casi en superficie. En la fig 3 se ve cómo están aparejados los portones.

Este equipo se utilizó por primera vez a mediados de febrero de 1969, con el objeto de identificar cardúmenes al NE del puerto de Mar del Plata, a una distancia de 80–100 millas del mismo. Los primeros resultados efectivos de captura se obtuvieron en el mes de marzo, en Golfo Nuevo, donde, en dos lances hechos con el objeto de identificar cardúmenes registrados en ecosondas y sonar, se capturaron 5 y 8 toneladas respectivamente, pasando la red sobre los cardúmenes no más de 10 minutos.

Con el mismo equipo, a fines del mes de marzo, se capturó por primera vez anchoíta que se encontraba casi en superficie, durante la noche. El sonar indicaba la presencia de cardúmenes dispersos, pero las ecosondas no registraban nada. Más adelante se explica cómo se modificó el aparejo para efectuar pesca superficial.

Las experiencias posteriores—en los meses de mayo, junio y julio, cuando se pescó en el talud de la plataforma submarina argentina a profundidades de 120 a 200 m—confirmaron plenamente que se puede capturar anchoíta utilizando redes de media agua, fuera de la época acostumbrada en Mar del Plata. Durante los meses nombrados anteriormente, esta especie se capturó tanto de día como

de noche, aunque la eficiencia de captura fue distinta. Con luz de día, los lances normales fueron de 10–15 toneladas, arrastrando entre 15–30 minutos. La pesca efectiva, cuando la red pasaba por el cardumen, duraba entre 3 y 8 minutos, lo que da una idea de la densidad del cardumen. Otras veces debía arrastrar más tiempo, debido a que los cardúmenes se encontraban más distanciados y había que situarlos con el sonar, siendo este equipo electrónico de gran valor para la pesca dirigida, en especial a gran profundidad.

Durante el día las capturas se hacían en profundidades que variaban entre 120 y 160 metros, las concentraciones de anchoíta eran muy densas y siempre se encontraban muy cercanas al fondo del mar; la temperatura del agua del mar en superficie osciló entre 11° y 13°C, y en fondo entre 7° y 9°C.

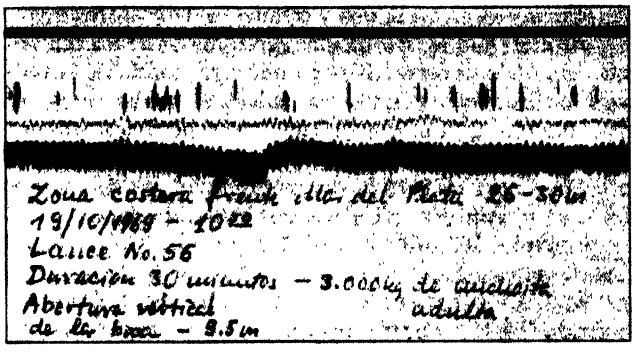


Fig 4. La pesca diurna en la zona costera

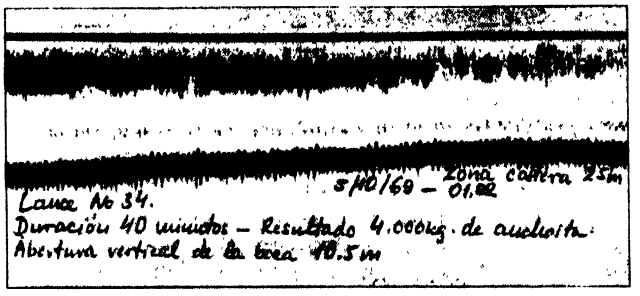


Fig 5. La pesca nocturna en la zona costera

Durante esta época del año los cardúmenes de anchoíta son poco activos y no tienen gran reaccción al acercarse la red, pues se comprobó repetidamente que la forma del cardumen detectado por la ecosonda del buque, al pasar sobre el mismo, se reproducía de la misma manera al entrar en la red y ser detectado por la ecosonda de la red.

Por la noche, las condiciones de captura y comportamiento del pez, varían. A la salida del sol y durante un tiempo que oscila entre 30 y 45 minutos, la anchoíta se concentra en cardúmenes densos que descienden hasta profundidades cercanas al fondo y se mantienen estacionarios. Al ponerse el sol, asciende en concentraciones más dispersas y menos densas, colocándose en fajas de 5 a 30 m de espesor, en profundidades que oscilan entre 10 y 60 m de la superficie según en qué fase se encuentre la luna; se comprobó que en los días de luna llena estas fajas de anchoíta oscilan entre 30 y 60 m y durante los días de luna nueva se concentran más cerca de la superficie, entre 10 y 30 metros.

Durante la noche, las capturas en general fueron menos efectivas que durante el día. Para la red de media agua, las capturas nocturnas variaron entre 6 y 8 toneladas por hora de arrastre.

El promedio del período mencionado (día y noche) fue, para la misma red:

mayo—6.500 kg/hora de arrastre
junio—8.600 kg/hora de arrastre
julio—7.100 kg/hora de arrastre

En base a las experiencias hechas con el "Cruz del Sur", durante 1969/70, se puede asegurar que en el período comprendido entre los meses de marzo hasta agosto, el uso de redes de media agua como la diseñada para ese buque sería de gran rendimiento para la pesca comercial de la achoíta. No se tienen aún datos adecuados

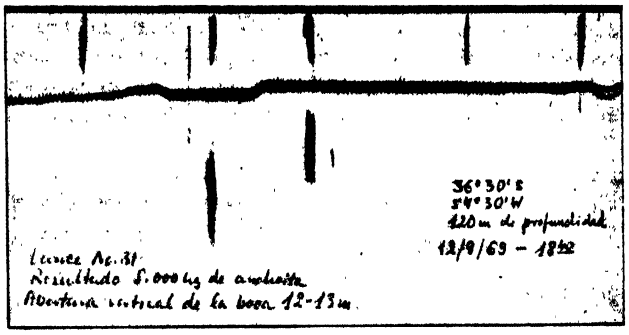


Fig 6. La pesca diurna en aguas profundas. Anchoíta con fuerte reacción

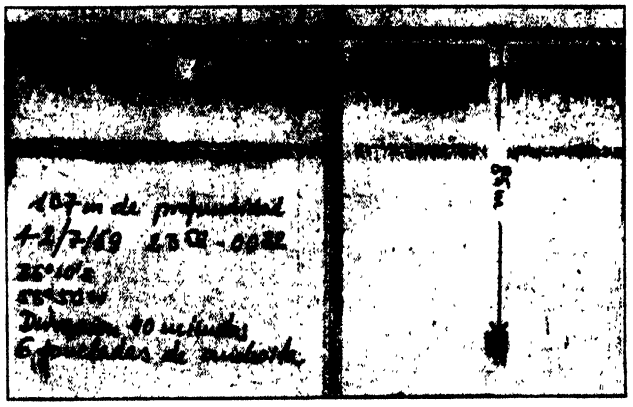


Fig 7. La pesca nocturna en aguas profundas

para el período comprendido entre noviembre y febrero y, durante los meses en que la especie migra hacia la costa—agosto y septiembre; la experiencia de este año en particular indica que:

(a) Los cardúmenes abandonan el talud continental con rumbo general sudoeste, comenzando a formarse las primeras concentraciones a fines de julio y comienzos de agosto.

(b) Se separan, son menos densos y ocupan diferentes niveles, a media agua, durante el día, dispersándose mucho por la noche en fajas poco densas.

(c) Las capturas se hacen muy difíciles. El sonar detecta los cardúmenes, los que también son detectados por la ecosonda vertical cuando el buque pasa sobre los mismos, pero en su mayoría, no se presentan el el transductor de la red. La pesca dirigida no es entonces muy aplicable ya que los cardúmenes tienen reacciones muy fuertes al buque y a los artes de pesca empleados.

Durante este tiempo, el rendimiento de la red de media agua bajó a 2–3 toneladas por hora de arrastre.

Más adelante se muestran algunos ecogramas característicos de los cardúmenes de anchoíta y su comportamiento. En las fig 4 y 5 se muestran los ecogramas obtenidos durante la pesca en aguas costeras. Las fig 6, 7, 8 y 9, muestran la pesca con red de media agua en aguas profundas y, especialmente las fig 8 y 9 presentan ejemplos de la pesca dirigida.

Como se observa en el ecograma fig 4, las concentraciones durante la época del "atraque a la costa" en 1969, formaban cardúmenes pequeños y dispersos. Por la noche, prácticamente no se podía utilizar la red y solamente en algunos lugares, antes de la salida del sol, los peces se agrupaban en concentraciones adecuadas para hacer buencas capturas—fig 5—siendo esos lances siempre los mejores. Posteriormente, a fines de octubre y comienzos de noviembre, el "Cruz del Sur" detectó concentraciones más grandes de anchoíta a más de 100 millas al sudoeste de Mar del Plata pero en esos momento no se experimentó con red de media agua sino con red de cerco, obteniéndose buenos resultados de captura.

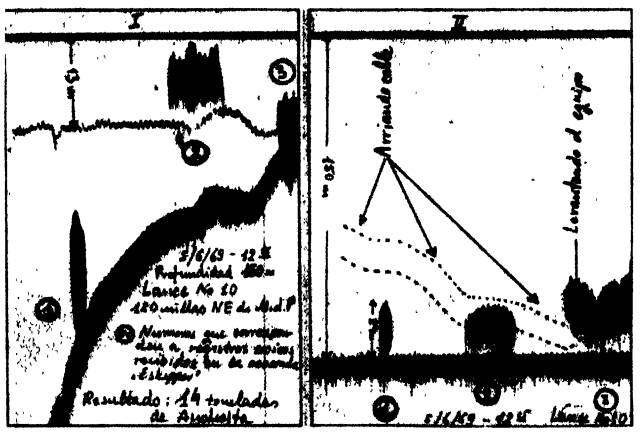


Fig 8. Ejemplo de la pesca dirigida

Fig 9. Otro ejemplo de la pesca dirigida. X = cardumen cortado por la mitad por la red de media agua

Cooperación del proyecto de la FAO con la industria pesquera

Los resultados de las experiencias con el "Cruz del Sur" se transmiten inmediatamento a los buques comerciales en el mar y a la industria pesquera en Mar del Plata. El Proyecto organizó conferencias sobre las posibilidades de explotación de los recursos naturales del mar argentino con redes de media agua y de cerco. Los armadores y capitanes de pesca consultan e intercambian información y conocimientos con los tecnólogos del Proyecto, para mejorar las técnicas en uso y obtener ayuda profesional.

Considerando los problemas económicos de los buques y la falta de equipo auxiliar (sonar y ecosonda de la red) para utilizar plenamente las redes de media agua, se aconsejó la utilización de una red diseñada por el Tecnólogo del Proyecto, para pescar en aguas cercanas a la costa, entre 15 y 25 m de profundidad. Varios armadores se interesaron para realizar esta experiencia y, en un principio, se contó con diez buques de altura de las características dadas al comienzo de este Informe, para ser equipados con una red de media agua como la sugerida (fig 10). Lamentablemente, por falta de acuerdo en los precios entre armadores e industriales, solamente dos buques se prepararon finalmente para hacer esta pesca.

Las características de estos buques, "Dorrego" y "Pancho Ramírez", que son gemelos, se dan a continuación: Eslora, 22, 50 m; manga, 7 m; calado, 2,80 m; potencia motor, 280 hp; tripulación total, 6 personas.

Los tecnólogos del Proyecto asesoraron a los capitanes en la técnica de pesca y aparejamiento del equipo. Más adelante se dan las capturas hechas por los dos buques.

En este caso es muy difícil hablar de eficiencia de pesca, ya que los dos buques trabajaron durante 28 días en el período octubre-noviembre, hasta un límite de 8–10 toneladas diarias de pescado para consumo, que fue el máximo que le recibía la industria. Al precio que tenía el pescado, esa cuota fue muy conveniente y rentable para estos buques. Durante los 28 días de pesca los buques trabajaron entregando el pescado en los puertos de Mar del Plata y Necochea y, si bien la campaña de anchoíta de este año fue pobre y distinta a los años precendentes, de todas maneras hubo días excepcionales en que en 24 horas de pesca se podían capturar hasta 50 toneladas. Estos días los buques aprovecharon para captura destinada a la producción de harina.

Debemos destacar tres hechos importantes e indiscutibles relacionados con las operaciones del "Dorrego" y el "Pancho Ramírez" durante esta temporada de pesca de anchoíta:

(a) Los buques tuvieron mejor rendimiento en tiempo y técnica de maniobra, en comparación con la tradicional pesca con la red de lampara. En esta última se utilizan dos lanchas y 10 personas para la captura de anchoíta y el trabajo es totalmente manual.

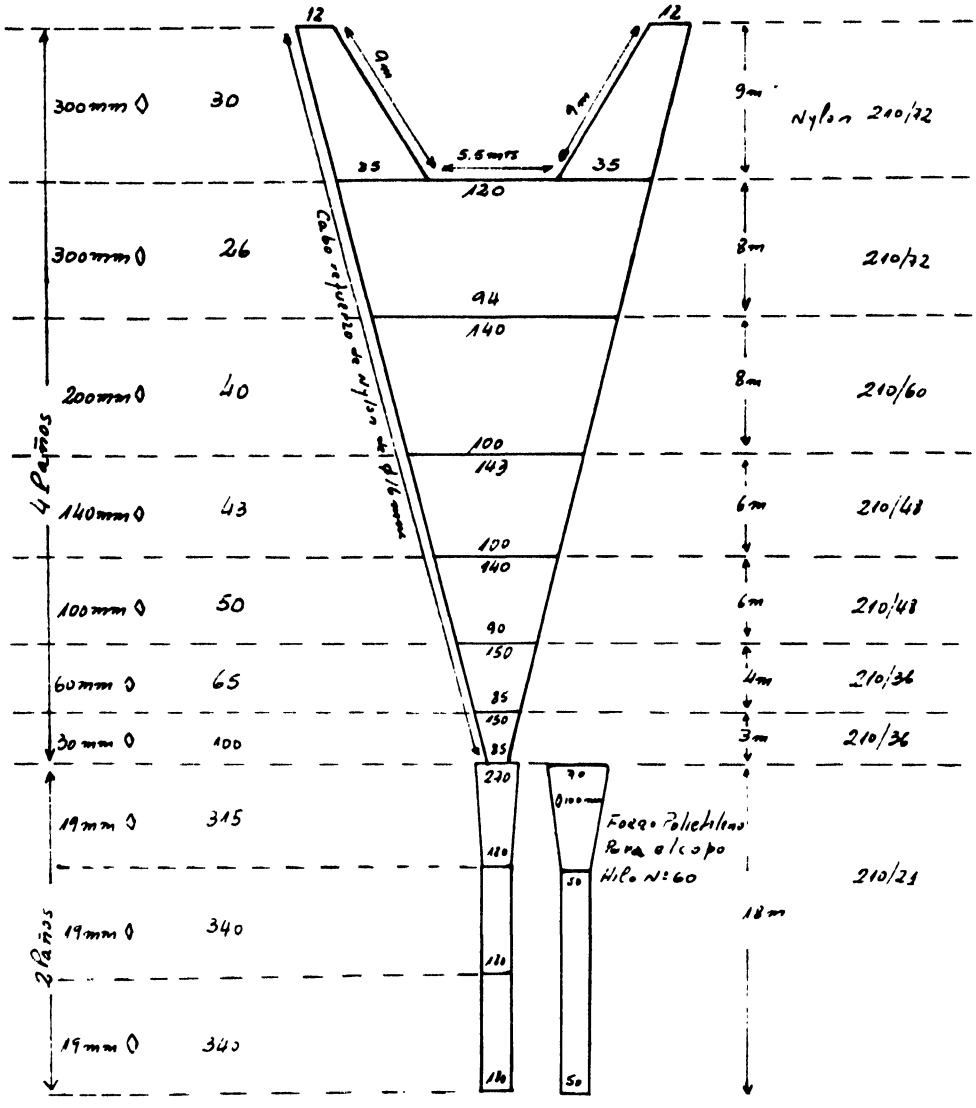


Fig 10. Red media agua 12 × 12 m. Buques de 250–250 hp

(b) Los buques trabajaron sin sonar y sin ecosonda en la red, o sea, sin control continuo.
(c) Los dos buques durante el período de exploración no tuvieron roturas en el equipo de pesca, utilizando la técnica de pesca indicada por tecnólogos del Proyecto.

La zona de pesca frente al puerto de Mar del Plata es muy peligrosa por su fondo irregular y rocoso, debiendo extremarse los cuidados para que la red no toque el fondo. La tabla ilustra los resultado obtenidos:

Buque	*Pancho Ramirez*	*Dorrego*
Días de pesca	27	28
N° de lances por día-promedio	4	4
Cantidad de captura:		
para consumo	210 toneladas	217 toneladas
para harina	50 (1 viaje)	50 (1 viaje)
Promedio rendimiento/lance	3-4 toneladas	3-4 toneladas

Los aparejos utilizados por los buques fueron similares al usado por el "Cruz del Sur". En página separada se muestra el diseño de la red, fig 10.

Tipos de explotacion propuestos de acuerdo con las redes de media agua utilizadas

Por las condiciones naturales del mar argentino, y las experiencias obtenidas del "Cruz del Sur", se sugiere aplicar los siguientes métodos de pesca:

En aguas profundas

(a) **Durante el día:** Hacer pesca dirigida; lances cortos, controlados por sonar y ecosondas. La red debe mantener una abertura de boca de aproximadamente 200 m² de superficie.
Velocidad de arrastre utilizada: 3,0 a 3,5 NS.

(b) **Durante la noche:** Control continuo de ecosondas para asegurar la posición de la red. Lances largos de 1 a 2 horas. Las interferencias causadas por la hélice, se eliminan bastante, trabajando con el timón inclinado 5° a 10° a cada banda.

El aparejo debe asegurar una buena abertura horizontal de la red; esta abertura se puede obtener en forma más

fácil, utilizando portones hidrodinámicos, del tipo Süberkrüb, por ejemplo. La velocidad de arrastre debe ser lo más alta posible (3,5 nudos), ya que la dispersión nocturna de esta especie es grande y el comportamiento más vivaz que durante el día. Se aconseja también para el trabajo de noche las bridas de 60 m de longitud, y de día 120 m. Además, es necesario aplicar en las bridas superiores, 1,5 m más de cable que en las inferiores, así como dar mayor fuerza de flotación a la red agregando flotadores, para llevar la red más fácilmente cerca de la superficie.

En aguas someras y costeras

Para la explotación en aguas costeras se recomienda utilizar un tamaño de red de media agua adecuado a la profundidad de explotación. (El tamaño indicado para los buques "Pancho Ramírex" y "Dorrego" probó ser correcto para las condiciones de pesca de esta temporada.)

Debe aplicarse la misma técnica que para pesca superficial nocturna en aguas profundas. El aparejo debe asegurar no solamente un buen trabajo a media agua, sino también, y ésto es muy importante para la zona de Mar del Plata, que la red en ningún momento toque el fondo, para evitar roturas. Para mantener la red siempre libre del fondo es necesario preparar las bridas superiores, 1,5 m más largas que las inferiores; de esta manera, la red trabaja además a un nivel un poco más alto que los portones. También es recomendable alargar la longitud de los cabos que sostienen las pesas principales, de manera que éstas toquen el fondo y eviten que la relinga inferior se arrastre por el mismo. Para los buques que no tienen ecosonda en la red y que por lo tanto no pueden controlar la boca de la misma, se recomienda observar continuamente la velocidad de arrastre. Durante todas las esperiencias en el "Cruz del Sur", se observó que velocidades de arrastre mayores de tres nudos son las más efectivas para la captura, especialmente cuando se encontraban cardúmenes pequeños y bastante separados.

PERSPECTIVAS DE LA PESCA DE MEDIA AGUA EN EL MAR ARGENTINO

En este trabajo se condensa la experiencia obtenida durante un año a través de las operaciones conducidas por la parte tecnológica del Proyecto de Desarrollo Pesquero.

El período de un año no fue suficiente para llevar a cabo todas las experiencias de la pesca con red de media agua, por haberse carecido del total del equipo necesario. No obstante, los resultados obtenidos autorizan a dar un panorama aproximado para el futuro.

Además, las experiencias obtenidas en el Atlántico Norte sobre el arenque y en Africa y en otros lugares sobre caballa, jurel y sardinella, pueden ser utilizadas como información adicional para lograr el mejor rendimiento del tipo de aparejo a utilizar. Hasta ahora, se observan dos líneas principales en las soluciones para para la pesca con redes de media agua.

(a) Gran superficie de la boca de la red para asegurar mejores capturas.
(b) Mayor velocidad de arrastre para asegurar buen rendimiento.

Es cierto que los dos factores son fundamentales para la pesca pelágica pero ¿cuál de esos dos es más importante para les condiciones de pesca de la anchoíta en el mar argentino? Para dar la respuesta justa y verdadera falta aún una mayor experiencia con distintos tipos de redes y tipos de explotación. Se sabe que si se aumenta el tamaño de la red, va a disminuir la velocidad de arrastre; y al contrario, si aumentamos la velocidad disminuirá la superficie de la boca y aumentará la resistencia. Encontrar la relación óptima entre estos factores es bastante difícil, en especial si se tiene en cuenta que también otros elementos importantes entran en la explotación, como son: tamaño de los barcos, potencia de los motores, estado del mar, meteorología, tipos de fondo y comportamiento de la especie durante un ciclo anual.

Así, durante las estaciones de otoño e invierno, en el mar argentino cualquier aumento en la superficie de la boca de la red a más de 200 m^2 parece ser muy útil en la práctica porque las concentraciones son densas y estacionarias. Por otra parte, en esta época, la velocidad de arrastre es más importante para pasar rápidamente de un cardumen a otro—éstos se encuentran a veces distanciados más de media milla—que para pasar sobre el mismo y asegurar de esta manera la captura. La disposición de reservas de velocidad durante el arrastre asegura el pasaje rápido de un cardumen a otro; además, el trabajo con este tipo de red, asegura rapidez en la maniobra por su fácil manipulación.

Al redactar este trabajo se piensa en la flota pesquera argentina, en la cual los buques son, en general, un poco más pequeños que el "Cruz del Sur" y la potencia de sus motores se limita a casi la mitad de éste. Por eso, los autores se inclinan más bien por las redes más pequeñas proporcionadas a la fuerza disponible de la flota pesquera.

Si se quiere extender la temporada de pesca de anchoíta, empleando redes de media agua, los buques de la flota argentina deberán ser equipados con sonar y ecosonda para la red. Durante esta época hay por lo menos cuatro meses que aseguran un buen rendimiento de captura, tanto de día como de noche, pero debe reiterarse que es improbable que la pesca comercial sea posible en el talud continental durante el otoño e invierno, si los buques no poseen, por lo menos, la ecosonda para la red o equipo equivalente.

En primavera, cuando los cardúmenes se acercan a la costa, podrán emplearse las redes de media agua sin el equipo auxiliar mencionado, pues durante esta época, las redes estarán limitadas en tamaño por la profundidad de trabajo (10–25 m) asegurando una mayor velocidad de arrastre. No obstante, aun en este caso resultará ventajoso disponer de una sonda de red.

Recent Developments in Midwater Trawling in the Pacific Northwest of the United States of America

R. L. McNeely

Innovations recentes interessant le chalutage mesopelagique dans le Pacifique au nord-ouest des etats-unis d'Amerique

En 1966 a été mise en route une petite pêcherie de merlu de Californie (*Merluccius productos*) dans le Puget Sound, utilisant le chalut pélagique Cobb mis au point par l'Exploratory Fishing and Gear Research Base du U.S. Bureau of Commercial Fisheries (BCF) à Seattle (Washington). La position des chaluts a été déterminée à l'aide d'un bathy-télémètre associé à des câbles de traction électro-mécaniques. La demande du marché a limité la production (en moyenne 3.500 tonnes par an). En 1967, on a ouvert une pêcherie de merlu (pêche au large) avec une aide matérielle fournie par le Gouvernement, mais son exploitation ne s'est pas révélée viable. On a employé plusieurs variantes du chaluts pélagique Cobb et du chalut universal BCF, ce qui a permis de comparer les taux de prise. Les taux de capture ont été de 46 pour cent supérieurs avec les filets en fibres monofilament qu'avec les filets classiques en fibres multifilaments. Le BCF poursuit ses recherches en vue d'utiliser le turet de chalut pour actionner une troisième fune allant se rattacher à la corde de dos et au bourrelet de façon à agrandir l'ouverture horizontale du chalut.

Recientes progresos en la pesca al arrastre entre dos aguas en el Pacifico al noroeste de los estados unidos

En 1966 se inició en el Estrecho de Puget una pequeña pesquería de merluza (*Merluccius productus*) utilizando la red pelágica de arrastre Cobb preparada en la Base de Pesca Exploratoria de Investigaciones sobre Aparatos de Pesca que la Oficina de Pesca Comercial de los Estados Unidos tiene en Seattle, Washington. Para colocar la red en posición se han utilizado batitelémetros comunicados con la embarcación mediante cables de remolque electromecánicos. La producción, con un promedio anual approximado de 3.500 toneladas, se ha visto limitada por la demanda del mercado. En 1967 se inició la pesca de la merluza en mar abierto con alguna asistencia material del Gobierno, pero no se logró establecer una pesquería viable. Se emplearon diversas variantes de la red pelágica de arrastre Cobb y de la red de arrastre Universal de la Oficina de Pesca Comercial, lo que permitri comparar los respectivos indices de captura. Utilizando paños de monofilamento se logró un indice de captura superior en un 46 por ciento al conseguido con los paños tradicionales de multifilamento. Las investigaciones que sigue realizando la Oficina de Pesca Comercial tienen por objetivo aprovechar el carretel de la red de arrastre para operar un tercer cable que vaya al centro de la relinga superior y de la relinga inferior para obtener una mayor abertura horizontal.

WITHIN the past decade there has been considerable progress in the development of one-boat midwater trawling. Although several countries are enjoying moderate to good success in such use, commercial usage in the United States is still limited. This is more closely related to economics of the fishing industry than to existing technology. In meagre trials at midwater trawling by U.S. fishermen, substantial catches have been made of hake (*Merluccius productus*), Alaska pollack (*Theragra chalcogrammus*), herring (*Clupea pallasii*) and dogfish shark (*Squalus suckleyi*). Since these are at present low priced industrial species, production of large catches does not result in high dollar yields. In the major food fisheries of the U.S.A. king crab, salmon, halibut, tuna, shrimp, haddock, perch and sole can at present best be taken using existing gear *and* use of trawl gear for capture of some species is illegal. Only perch, haddock and several varieties of lesser important rockfishes might be more efficiently taken with midwater trawls during certain periods of the day or year.

Midwater trawling experiments in the U.S.A. have been conducted mostly by federal and state fishery agencies due to the cost involved and to date none have shown that higher priced food fish can be regularly taken more economically in midwater trawls than with conventional gear.

Puget Sound midwater trawl fishery

Considerable progress has been made in development of midwater trawling gear to capture pacific hake and a small fishery has developed in Puget Sound, Washington. This fishery produced 3000 t of hake during the 1966 season (January through April) and has since continued to be an off-season fishery, providing a modest income for two to six vessels who land their catches at small reduction plants for conversion to fish meal, pet

TABLE 1. CHARACTERISTICS OF COBB PELAGIC TRAWLS AND B.C.F. UNIVERSAL TRAWL

Trawl	*Designed mouth opening*	*Meshes across mouth*	*Meshsize stretched in body mm*	*Twine size, R-tex or mm*			*Recommended horsepower hp*
				Top and Sides	*Wings*	*Bottom*	
Cobb Pelagic Trawls							
600 monofil	22.8×22.8	600	76	1.1×0.6	1,550	2,810	500
Standard 18	22.8×22.8	600	76	1,360	2,810	2,810	630
440	16.7×16.7	440	76	1,360	1,360	1,360	330
2/3	15.2×15.2	600	51	1,360	1,360	1,360	380
600-21	22.8×22.8	600	76	1,550	2,810	2,810	650
640 monofil	24.3×24.3	640	76	1.1×0.6	1,550	2,810	530
648	20.7×20.7	648	64	1,550	1,550	1,550	500
				825	825	825	
B.C.F. Universal Trawl	20.7×12.2	650	64	1,550	2,810	2,810	350

Conversion: 1 ft = 0.304 m; 1 in = 2.54 cm; R-tex = US thread size No. x 75; R-tex = weight in g/1,000 m of finished net twine.

food or fish food pellets at fish hatcheries. Prices paid for the raw fish have ranged from US$12 to $25/t, depending on the price of fish meal and ultimate usage of the fish, e.g. meal, pet food or pellets. The number of vessels engaged is dependent on market demand rather than availability of fish. The fishery started as a result of loan of midwater trawl gear developed by the Bureau of Commercial Fisheries (B.C.F.), Exploratory Fishing

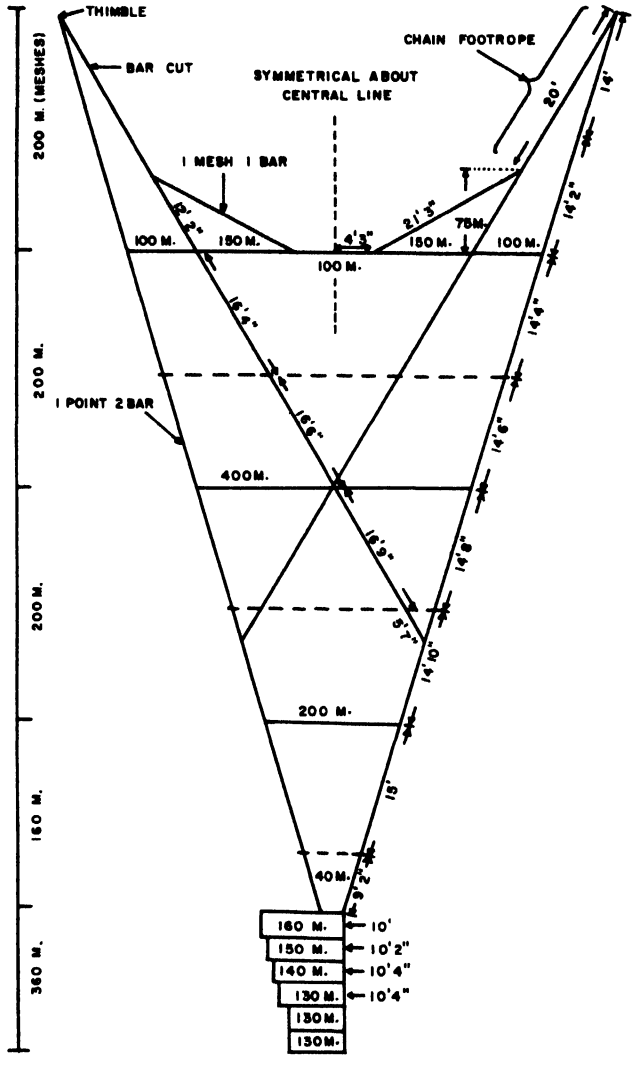


*Fig 1. 2/3 Cobb pelagic trawl. Materials: Body web 2 in—*18-thread nylon; cod-end web 2 in—*60-thread nylon; corner riblines ⅜ in braided nylon; crisscross riblines ½ in—braided nylon; use conventional puckering rings and splitting strap assembly. Note that all four sides are equal, suitable for 380-hp vessels, otter boards must be at least 44 sq ft*

and Gear Research Base, Seattle, Washington (McNeely *et al*, 1965) on a trial basis. The gear was loaned to the trawler *St. Michael* whose immediate success led to a second vessel, the *St. Janet*, entering the fishery, also provided with most of the necessary equipment on a similar loan-trial basis. Both vessels fished 2/3 scale "Cobb" pelagic trawls (fig 1) complete with hydrofoil otter boards and an electrical depth telemetering system (Lusz, 1967; 1970).

Using computer analysis of those tows considered significant (tows made within 1 minute of longitude and 1 minute of latitude within one hour of each other for study of gear efficiency relative to the standard 600-18 Cobb Pelagic Trawl (fig 4)) the following results (Table 2) were obtained.

TABLE 2. RELATIVE CATCH RATES OF COBB PELAGIC TRAWLS AND B.C.F. UNIVERSAL TRAWL

Trawl	*Relative Catch Rate*
Cobb Pelagic Trawls:	
640 monofilament	1.46
600 monofilament	1.13
648-12	1.04
600-18	1.00
600-21	0.74
B.C.F. Universal Trawl	0.83

During the entire season, the *St. Janet* landed 1500 t of hake and broke all previous records of trawl landings in the state of Washington. This is remarkable as the *St. Janet* is a 50-ft (15.24 m) "Alaska limit seiner" type vessel having only 200 hp. During the entire season the *St. Janet* **averaged** over 12 t of fish per hour towing. The *St. Michael* also had a good production record averaging slightly over 10 t per hour towing, even though she has 350 hp and is 78 ft (23.8 m) in length. Two additional vessels entered the fishery late in the 1966 season and attempted flying conventional bottom trawls off bottom, but soon converted to midwater trawls as their catch rates were only about ½ the catch rates of the *St. Janet* and *St. Michael*. In the 1967 season these two additional vessels were provided with Government-owned electrical towing cables and depth telemetry systems and their catch rates improved to a level comparable to the *St. Janet* and *St. Michael*. The total production in 1967 was about 4500 t which was determined primarily by market conditions as the vessels were restricted to limited production most of the season. In 1968 no Government-owned equipment was provided and the fishery has continued without Government assistance and during the 1970 season six vessels were engaged and production was slightly over 4000 t.

Offshore commercial fishery trials

During the summer of 1967, the B.C.F. conducted a simulated commercial fishery for hake off the coast of Washington and Oregon to determine the economic feasibility. Ten vessels were chartered and outfitted with electrical towing warps for depth telemetry, Cobb Pelagic Trawls and B.C.F. Universal Trawls (figs 2 and 3). The vessels landed and sold their catches at a reduction plant in Aberdeen, Washington. Price paid for the fish was US$16/t. The top four vessels realized gross earnings of US$375/day from the sale of fish. However, at the conclusion of the charter period (approximately two months) all vessels departed from the fishery although fish were still abundant and extension of loan of gear was offered. Some of the vessels averaged 6 t of fish per hour towing, while the top boat averaged nearly 7 t per hour towing. Catches of approximately 25 t/tow were common and several catches in excess of 50 t/tow were made.

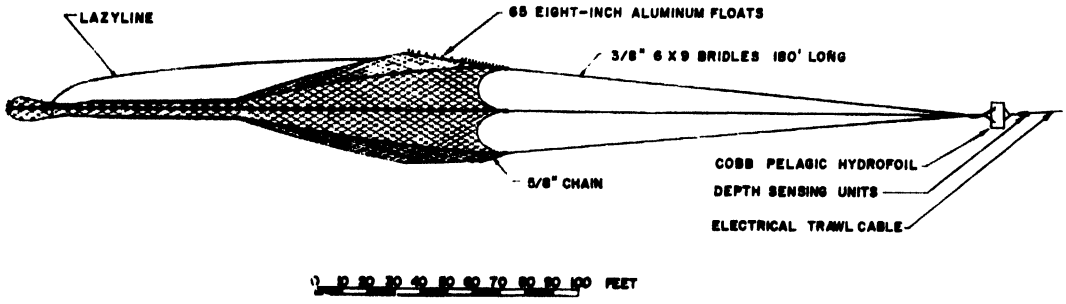
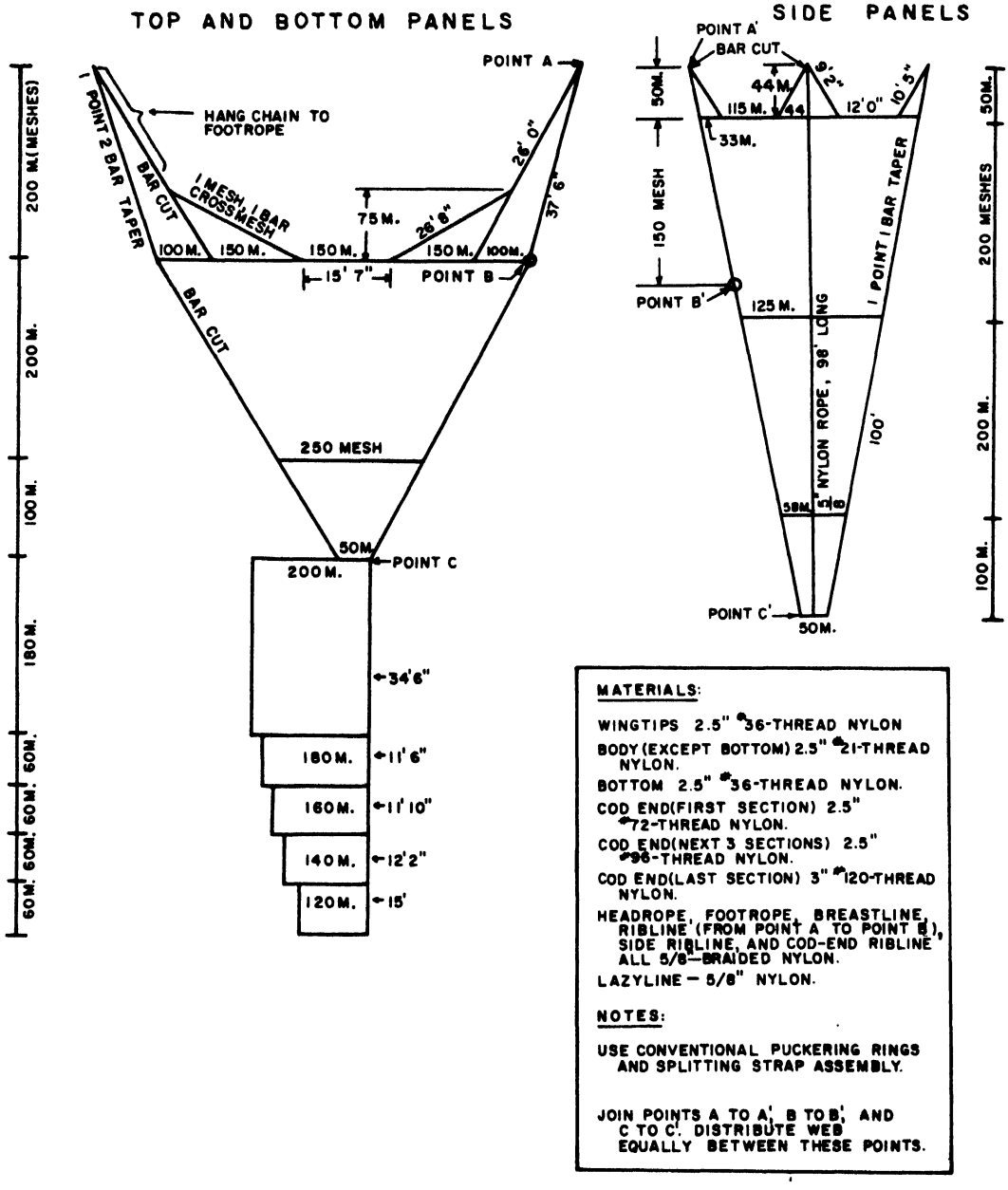


Fig 2. BCF Universal trawl, side view, to scale



MATERIALS:

WINGTIPS 2.5" #36-THREAD NYLON
BODY (EXCEPT BOTTOM) 2.5" #21-THREAD NYLON.
BOTTOM 2.5" #36-THREAD NYLON.
COD END (FIRST SECTION) 2.5" #72-THREAD NYLON.
COD END (NEXT 3 SECTIONS) 2.5" #96-THREAD NYLON.
COD END (LAST SECTION) 3" #120-THREAD NYLON.
HEADROPE, FOOTROPE, BREASTLINE, RIBLINE (FROM POINT A TO POINT B), SIDE RIBLINE, AND COD-END RIBLINE ALL 5/8"—BRAIDED NYLON.
LAZYLINE — 5/8" NYLON.

NOTES:

USE CONVENTIONAL PUCKERING RINGS AND SPLITTING STRAP ASSEMBLY.

JOIN POINTS A TO A', B TO B', AND C TO C'. DISTRIBUTE WEB EQUALLY BETWEEN THESE POINTS.

Fig 3. BCF Universal trawl

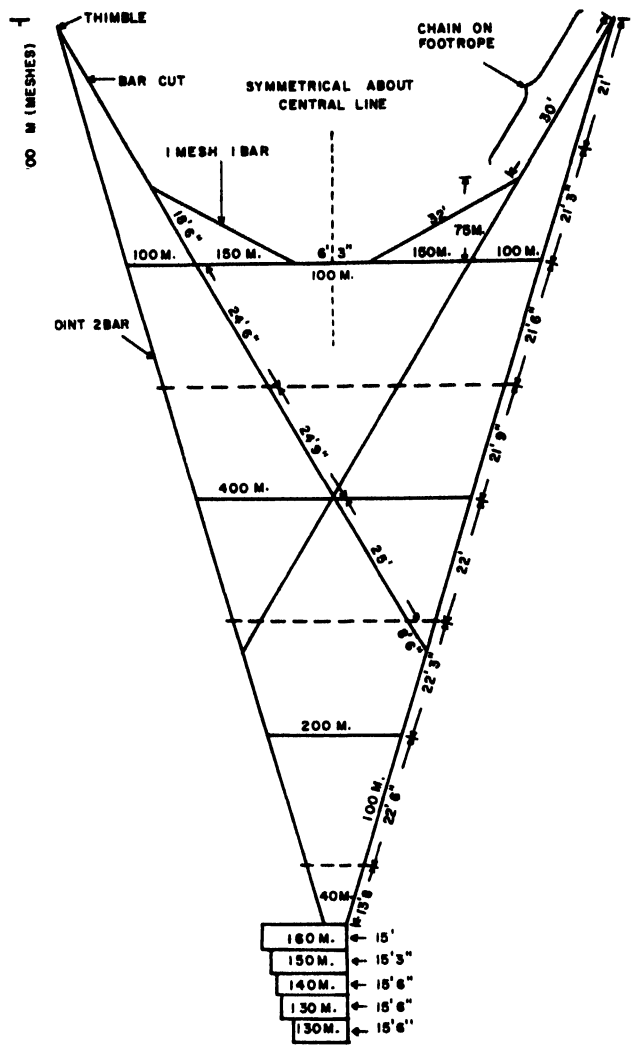


*Fig 4. Standard 18 Cobb pelagic trawl. Materials: Body web 3 in—*18-thread nylon; cod end 3 in—*96-thread nylon; wings and bottom 36 thread, corner riblines ⅜ in—braided nylon; crisscross riblines ¼ in braided nylon; use conventional puckering rings and splitting strap assembly. Note that all four sides are equal; suitable for 630 hp vessel; otter boards must be at least 72 sq ft*

Most of the vessels were small, having only 150–300 hp and bulk fish carrying capacity of 60 t of raw fish. The two top boats had 400 and 500 hp and fish carrying capacities of approximately 100 t (fig 5).

Results of 1967 offshore fishing trials

In addition to gaining considerable information on commercial feasibility of an offshore midwater trawl fishery for hake, much valuable information was gained on the relative efficiency of a variety of modifications to the Cobb Pelagic Trawl, including use of monofilament netting, and the B.C.F. Universal Trawl. The monofilament netting was made of light weight, eliptical cross section (1.1 mm×0.6 mm) filaments. Since the various nets were exchanged among all the vessels and fished at different time periods, the data must of necessity be considered empirical rather than significant. General characteristics of the trawls used in the experimental fishery are shown in Table 1.

Fig 5. 30 t catch of Pacific hake taken in BCF Universal trawl by trawler St. Michael *(350 hp)*

Current research and prospects for the future

Although an abundant hake resource exists off Washington and Oregon the 1967 trials showed that the catch rate needed to be improved even further before a viable offshore fishery could be established. Based on this premise, information gained from the 1967 trials has been used to design more effective gear. Since an analysis of the average depth of hake schools (from prior years' echograms) showed than an accurately positioned net need not have more than 30 ft (9.1 m) vertical opening, research efforts have been directed to increasing the horizontal openings without much increase in size of the

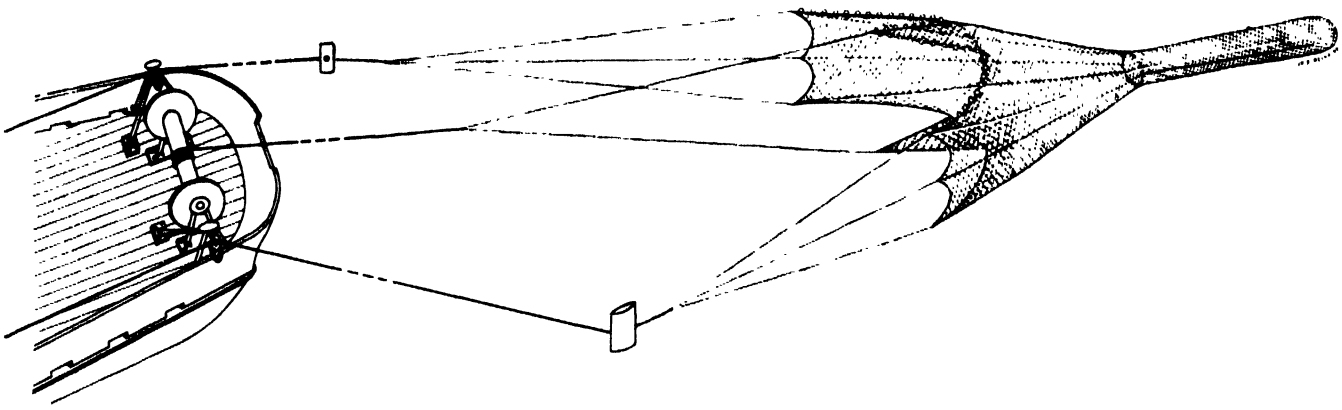


Fig 6. Three-warp towing system used with the "Multi-Bridle" trawl

trawl, size of the otter boards, or horsepower. To accomplish this a novel design in trawl gear has evolved.

"Multi-bridle Trawl"

Taking into account that most NW Pacific trawlers are equipped with trawl net reels on the stern and that the principal function of otter boards is to exert a horizontal force for opposing the collapsing force of the net, we decided to utilize the net reel as a third towing warp winch and thus apply a towing force through a central towing warp down the centreline of the top and bottom of the trawl. The objective was to reduce a portion of the horizontally collapsing force, thus allowing a greater horizontal opening at a slight sacrifice of vertical opening (fig 6).

To test the feasibility of this hypothesis, additional wing sections, cut on the bar, were added to the top and bottom bosoms of a B.C.F. Universal Trawl and riblines were installed with the netting hung in 13.4 per cent from the new wing tips down the centre of the top and bottom of the net sections to the codend. Underwater inspection by scuba-divers showed an increase of slightly more than 25 per cent in horizontal opening and an estimated 20 per cent decrease in vertical opening between upper and lower bosom without any change in vertical opening of the port and starboard wings. The two additional riblines depressed the new wings and body of the net as was to be expected. This modified net was then fished for only a few tows on poor echo traces of fish but produced greater than expected catches of green rockfish (*Sebastodes flavidus*).

The modified trawl, having shown promising results, was then disassembled and a new multi-bridle net was designed specifically for three warp midwater trawling. It is similar in design to the modified B.C.F. Universal Trawl except that it has polypropylene netting, 125 mm meshsize stretched in the wings, 75 mm meshsize stretched nylon monofilament in the major portion of the body, 63 mm meshsize stretched netting in the intermediate and a codend of sufficient length and diameter to easily handle catches of hake in excess of 100 t. In addition to normal splitting rings, for splitting aboard about 1½ t of fish per split, a second set of splitting rings are installed further forward to split off about 15 t of fish from the remainder of the catch for easier handling during splitting operation. Tests with the new net were scheduled for summer, 1970.

An additional, obvious benefit to this method of trawling is that electro mechanical towing cable, terminated at waterproof sliprings on the net reel winch, can be used to operate various transducers for depth indication, aiming the trawl or measurement of other parameters of the gear or environment in the area of the trawl (Schärfe, 1968–69).

Since it is likely that even larger sterntrawlers will ultimately install net reels for handling large midwater trawls and most employ a third winch for handling netsonde equipment, it is only natural to predict eventual utilization of the multi-bridle concept with its obvious advantages.

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DISCUSSION

AIMED TRAWLING TECHNIQUES

Schärfe (FAO) Rapporteur: The techniques and tricks of "aimed" trawling are essentially the same for bottom, semi-pelagic and pelagic trawling. Only the emphasis on particular aspects such as bottom depth, configuration and material, and

the efficiency of some tools, such as sonar for fish and gear location differ according to the mode of operation, which naturally is ruled by the distribution, movements and reactions of the fish.

One of the main features of "aimed" trawling is its versatility which enables rational adaptation to varying fishing conditions and fish distribution to a large extent without the need, as currently, for essential specific local fishing experience. In other words, a skilled skipper adequately equipped for "aimed" trawling can much more efficiently react to varying conditions or start fishing on unknown grounds with much less risk and a better chance of success than is the case with conventional techniques.

Apart from essential instrumentation which has just been discussed this versatile operation in midwater, close to the bottom or on the ground naturally requires adequate trawl gear and there is no uniformity of opinion yet as to whether a universal bottom and midwater trawl (**McNeely**; **Kodera**), or specific and quickly exchangeable trawls, are the better solution. This important point, which, apart from the question of distribution, also has a bearing on the species of fish sought, should possibly be discussed here in greater detail. I tend to the latter solution, i.e. three different trawls, a small and heavy one for rough bottom, a large and light one with high-opening for smooth bottom and a midwater trawl.

These aspects are considered in **Maucorps** and **Portier's** paper on herring trawling in which the decisive importance of fish detection and observation with echo sounder, sonar and netsonde is particularly emphasized. The same stress is made in the contributions of **Drever** on bottom trawling, **Calon, Maucorps** and **Portier** on semi-pelagic and pelagic trawling, and **Kodera** and also **Kudryavtsev** on midwater trawling.

The virtues of sonar and netsonde are unanimously agreed on for midwater and semi-pelagic trawling but do not seem to be generally recognized yet for bottom trawling. They are not, for instance, mentioned by **Drever. Vestnes** mentions the ability of sonar to reveal bottom configuration ahead which is well known and applied in some fisheries for avoiding rocks or patches of rough ground and also for contour trawling.

Apart from indicating the proper performance of and eventual damage to bottom trawls and showing the fish, the echo sounding netsonde also allows the skipper to judge bottom quality and to jump the net over obstacles. The use of netsonde in bottom trawling, which seems to be almost routine in certain Japanese trawl fisheries, is strongly recommended.

Examples of specific conditions and respective fishing techniques are given by **Drever** for roundfish bottom trawling and by **Calon, Maucorps** and **Portier** and **Kodera** for semi-pelagic and pelagic herring trawling, and by **Savrasov** for several other pelagic species. These "aimed" trawling techniques which are still developing stretch over such a wide field that it cannot be hoped to cover them adequately here.

One point should however at least be touched on and that is the question of gear size versus towing speed or in other words "Chasing" versus "outwitting" to which hardly any reference has been made in the papers. The netsonde observation of fish together with net speed measurements has revealed that under certain conditions a large net at low speed is far superior to an inevitably smaller net at high speeds. One example given in my review is migrating Atlanto Scandic herring. The choice between "chasing" the fish at high speed and trying to catch it in a small trawl or "outwitting" the fish by smoothly guiding it at low speed into a a large net, is obviously of significance, not only for the selection of the gear, but also for the specification of the trawler, its deck layout and its auxiliaries. At least some discussion would be desirable to help clarify which of the two concepts offers the wider application with regard to known fishing conditions. Because of the well known physical facts mentioned yesterday, outwitting is particularly advantageous for low powered trawlers. Needless to say, I am clearly in favour of this concept.

In closing I would like to stress that "aimed" trawling is not basically restricted to highly developed fisheries with powerful and sophisticated vessels and gear. By selecting the most essential instrumentation, e.g. a simple echo sounding netsonde and simple means for speed and warp angle measurements this concept can very well be applied also in small vessel operation and in developing countries as FAO has started to do in several of its field projects (e.g. **Okonski** and **Martin**).

Okonski (FAO, Argentina): I would like to outline some aspects which I think are of basic significance for the selection of trawl size and towing speed. I think we all agree that the reactions of fish depend on its physiological state, the water temperature and the transparency of the water. For some fish species the reaction pattern under various conditions and the maximum swimming speed are reasonably well known and it is therefore possible to assess the distance at which their reaction will occur. Assuming that this reaction will be flight at maximum speed the ineffective part of the net opening or respectively the zero-efficiency of the trawl with regard to size of the net opening and the towing speed can be calculated. Zero efficiency is defined as the unproductive area of the trawl mouth when towing at maximum swimming speed of the fish species in question. Obviously an increase of towing speed and trawl opening size will increase fishing efficiency. On local fishing conditions and on economic consideration will depend which of the two measures is preferable and to what extent it can be increased.

Muschkeit (Germany): I think the biggest net with highest speed is the best. With no Atlanto Scandic herring left German trawlers now work predominantly off the New England coast where herring schools are mostly found on or close to the bottom. For these conditions smaller midwater trawls and higher towing speeds are considered more efficient.

Schärfe (FAO) Rapporteur: One cannot have both the largest net *and* highest speed, and compromise will have to be made. The problem at hand is which of the two extremes should be emphasized for optimum efficiency and this decision will naturally depend on the trawler, fishing conditions and the distribution and behaviour of the fish. As an example, during midwater trawling trials **Muschkeit** and I made with his trawler *J. Homann* (2000 hp) on migrating Atlanto-Scandic herring north of the Faroe Islands, the net with a front meshsize of 56 cm stretched had an average opening size of about 35 m (height) by 50 m (width) and the towing speed was in the order of 2.0 to 2.5 knots, which was certainly the highest speed obtainable. Considering that the maximum swimming speed of this herring is in the order of 5 to 6 knots this to my definition was "outwitting" and not "chasing". Incidentally, during these trials the average catch was per towing hour 46 t and a total of 275 t of this herring was caught in eight tows totalling 6 towing hours.

Parrish (UK): There could be dangers in generalizing on the question of gear size versus towing speed. **Schärfe** seems to be making his main point with regard to midwater trawling and to herring. As you know in the UK there have been developments in increasing the size of bottom trawls and the fishing results of such a trawl in comparison with the existing smaller trawl tended to highlight the importance of fish behaviour aspects.

Schärfe (FAO) Rapporteur: I am quite aware of this danger of generalization and my suggestion is to pool our knowledge and eventually inspire suitable investigations to determine

which of the two concepts has wider applicability. This objective is certainly not to be restricted to midwater trawling nor to herring. For several reasons I am more inclined towards "outwitting": the concept is unconventional and little is known about it so far; the good results with active migrating Atlanto-Scandic herring indicate that it may also work on other fish under different conditions; it is in better tune with the physical facts than "chasing" and therefore technically preferable. I expect that adequate experimentation and trials will show that "outwitting" has considerable scope in commercial trawling.

Okonski (FAO, Argentina): The importance of accurate comparative fishing trials for the evaluation of gear size versus towing speed must be stressed. The results will be strictly true only for respective fish species under trial conditions.

Sigurdsson (FAO): On grounds where damage to bottom trawl nets cannot be avoided, which applies to most grounds where Icelandic trawlers operate, large nets have been unsuccessful because the increase in catch does not compensate for the loss of time for mending such large nets. Consequently, we prefer to use small nets.

Frimannsson (Iceland): According to the Bulletin Statistic of the ICES for 1967 German pelagic trawlers caught 10,200 t of herring in 422 days which is about 25 t per day. This does not appear to be as effective for, say, 1000 BRT vessels as many people claim. I would like to know if anyone has any other data on long term catch rates with pelagic trawls.

Keirat (Germany): More recently, German trawlers averaged during the season 45 to 50 t of herring per day and 35 to 40 t per day in the off-season.

Gronningsaeter (Norway): Asked for information of the success of German midwater trawling off the Norwegian coast, particularly with regard to saithe (*Pollachius virens*) which often dive down to the bottom and may therefore not lend themselves so well to midwater trawling.

Keirat (Germany): When I telephoned my company this morning I was told that one of our trawlers fishing off the North Norwegian Coast caught up to 25–30 t of saithe per day.

Muschkeit (Germany): I can confirm that our company has success in midwater trawling off the Norwegian coast with catches of up to 25 t of saithe. This fish can travel at high speed but is often near the bottom so that the footrope of the midwater trawl must be close to the sea bed. Good results have also been obtained fishing for pole-shaped echo traces off the Norwegian coast. The catch may then be mixed, i.e. about one-third cod and two-thirds saithe.

McNeely (USA): In the US we were somewhat forced into attempting the design of a trawl that could be used both in midwater and on the bottom in the Pacific Northwest hake fishery. The reason for this is the behaviour of the fish. Often we locate fish in midwater with the echo sounder, turn the vessel around, shoot the gear, and then find that the fish have changed their position (from 4 to 6 fm off bottom) to on-bottom. At other times we find them on the bottom and during the progress of the tow they rise off-bottom. Now, its obvious that we cannot change gear in the middle of a tow and this explains why we continue to experiment with the universal trawl concepts.

Kristjonsson (FAO): One important point we have skipped over lightly is that the technique of aimed trawling was first applied on a large scale in Japan as a direct result of the first FAO Gear Congress in 1957. Papers presented at that Congress and published in *Modern Fishing Gear of the World*, Vol. 1, reported the development of the netsonde in the UK and the Süberkrüb boards in Germany. But no commercial fishery resulted in Europe. Between 1960 and 1963 over 300 fishing units using Süberkrüb boards and netsonde were in operation in Japan. The Japanese beat Europe by more than five years. Süberkrüb boards and netsonde were used on bottom trawls, off-bottom trawls and midwater trawls and these were generally very big nets.

One-boat Midwater Trawling

A. v. Brandt

Le chalutage pelagique a un bateau

L'historique du développement du chalutage pélagique à un bateau dans différentes régions du monde met en évidence le progrès important accompli au cours des dix dernières années. La taille des chaluts s'est accrue avec l'augmentation de puissance des chalutiers. Ceci a influencé les matériaux pour les filets, le dimensions des panneaux, les poids, les flotteurs et la longueur des bras. A cause des avantages qu'il présente en opération et en manoeuvre par rapport au chalutage pélagique en boeufs, le système à un bateau est devenu une méthode de pêche importante pour les grandes unités. On donne des exemples de quelques types importants de chaluts pélagiques à un bateau (Tableau 1). Les plus grands filets sont à quatre coutures (les chaluts à deux coutures sont plus petits). La plupart des panneaux hydrodynamiques sont du type Süberkrüb. De nombreux essais ont été effectués pour améliorer les dispositifs de divergence. Dans la majorité des cas, des dispositifs simplifiés ont remplacé les systèmes compliquès. La télémesure au netzsonde de la profondeur du chalut et du poisson à capturer est importante et décisive pour une pêche "contrôlée". Des systèmes améliorés de multi-netzsonde commencent à être employés commercialement. La possibilité de chaluts polyvalents pour la pêche au fond et entre deux eaux est encore discutée et il paraît douteux que les chaluts universels constituent la meilleure solution. De bons résultats sont obtenus avec des chaluts semi-pélagiques comportant des panneaux frottant le fond et un bourrelet flottant à quelques mètres au-dessus du fond. Quelques remarques sont faites au sujet des tendances futures signalées dans les publications.

Pesca al arrastre entre dos aguas con una embarcación

La historia del desarrollo de la pesca al arrastre entre dos aguas con una embarcación, en diferentes partes del mundo, demuestra un importante adelanto en los últimos diez años. El tamaño de las redes de arrastre aumentó al incrementarse la potencia de remolque de los arrastreros. Esto influyó en los materiales de la red, tamaño de las puertas de arrastre, lastres, flotadores y longitud de la malletas. A causa de las ventajas en su funcionamiento y manipulación, en comparación con la pesca al arrastre entre dos aguas en parejas, el sistema de una sola embarcación se ha convertido en un importante método pesquero para grandes unidades de pesca. Se dan ejemplos de algunos importantes tipos de redes de arrastre entre dos aguas con una sola embarcación (Cuadro 1). Las redes de arrastre mayores son de cuatro relingas (las redes de dos relingas son pequeñas). Casi todas las puertas de arrastre hidrodinamicas son del tipo Süberkrüb. Se han efectuado muchos experimentos para mejorar los dispositivos que modifican la oblicuidad. En la mayoría de los casos los instrumentos más complicados se han sustituido por ostros menos complicados. La telemetria con "netzsonde" de la profundidad a que está el arte y de los peces que se han de capturar es importante y decisiva para la pesca "dirigida". Se están empezando a vender en el comercio "netzsonde" múltiples mejoradas. La posibilidad de emplear redes de cerco para fines múltiples en la pesca de fondo y entre dos aguas se está discutiendo todavía, existiendo dudas acerca de si las redes de arrastre universales serían la solución óptima. Tiene éxito il empleo de redes de arrastre semipelágicas con peurtas que barren el fondo, y con la relinga del fondo flotando a unos metros de distancia del fondo del mar. Se hacen observacionces sobre las tendencias futuras expeurtas en las publicaciones sobre este tema.

THE history of the development of one-boat midwater and surface trawls reaches far back and examples are known not only from Europe but also from the Far East. The main problem was to keep the net open horizontally and this could be solved with a single boat by broadside sailing only. By this towing speed and gear size were limited.

After the invention of otter boards more than a hundred years ago the efforts to develop a one-boat midwater trawl were encouraged very much, especially in those countries of NW Europe where bottom trawling with otter boards became the most important or dominating fishing method in sea fisheries. Some results of these efforts are preserved because patents were granted in the first decade of this century. There was now available enough power to tow midwater trawls with a large opening by a single vessel, but attempts failed because another prerequisite, like continuous depth control of the trawl, could not be solved and nothing was known about fishing tactics in midwater trawling.

BASIC IDEAS FOR TRAWLING IN MIDWATER

As far as can be seen from patents and literature three proposals were made:

(a) Weighted trawl suspended on water surface by means of floats with depth regulated by the length of the connecting lines between floats and net. The same can be done by fixing a trawl with high buoyancy to a sledge towed over the bottom. (Midwater trawls suspended by long lines from surface floats are still used today.)

(b) Trawl with high buoyancy (due to floats or towing speed) but fitted with a depressor; net depth regulated by length of warps, size of the depressor and/or towing speed, e.g. the Isaacs-Kidd trawl.

(c) Trawl has slight negative buoyancy, a little less than the weight of the footrope then net depth can easily be regulated by the length of warps and/or towing speed. (This is now the most important method used in midwater trawling.)

It was found, however, that it was not enough to know only how to control the depth of the gear. Many experiments, mostly not published, brought no success, but this changed completely when fish finding echo sounders were introduced.

One-boat and two-boat systems compared

With the development of echo sounding, two-boat midwater trawling has become a successful commercial fishing technique since 1949. Nevertheless, attempts to find an economic solution for one-boat midwater trawling were continued, mainly because the two-boat system was not acceptable for larger trawlers. The main characteristics of both systems have been compared by Schärfe (1969c). The advantages of one-boat midwater trawling are:

(a) It is easier to exchange with bottom trawling; only one skipper is required (in pair-trawling essential good teamwork between two skippers is often difficult to achieve).

(b) Manoeuvring is easier (for pair-trawling manoeuvring, especially on crowded grounds, is not easy and it is more difficult to turn 180°).
(c) Fishing can be continued in bad weather.

Disadvantages of one-boat system are higher engine and winch power needs with the risk of scaring fish by vessel transit. The latter can be minimized by long bridles, though this makes manoeuvring difficult.

Net depth gauges

Warp length and speed are regulatives for fishing depth on midwater trawl which is limited by available length of warps, winch and engine power. In the beginning the net depth was calculated from the inclination of the angle of the warps with the horizontal (a) and the warp length (AB). The net depth (D) could conveniently be taken from nautical tables with the formula $D = AB \times \sin a$.

This and other calculations neglect the fact that a longer warp is not a straight line. To increase accuracy, calculated tables were worked out by scientific institutes and netmakers, partly corrected by observations of scuba divers and submarines (Truskanov and Zaitsev, 1959) or measurements with depth gauges. Even today such tables are still used, mainly by small vessels (Kamenskij and Trebusnoj, 1960; Dolbis, 1960; Hamuro and Ishii, 1960; Nakasai and Kawakami, 1965).

To improve reliability of midwater trawling a more accurate and real-time depth measurement was required. Therefore depth telemeters with continuous indication on board during towing have been developed, most of which measure the hydrostatic pressure and thus the distance of the trawl from the surface. Data transmission from net to trawler is through special cables, electric conductors in the warps, or by tube connection. Wireless acoustic links have also been developed and their reliability seems to have been improved considerably recently. Comparative virtues of cable or wireless transmission are still under discussion (N.N., 1965a; McNeely, 1968).

Suitability of electrical towing warps for transmitting data from pressure sensors are discussed by McNeely (1968). Main advantages of this system in avoiding separate cables and the need for an additional winch must be placed against certain drawbacks, such as need for special fittings and, in particular, repairing the electrical warp when damaged or broken.

The actual problem in midwater trawling is to reliably coordinate the depth of the trawl opening with the sometimes changing depth of the fish to be caught. Mere depth telemeters are inadequate because they do not show the fish at the trawl.

Trawl depth and fish finding

Some pelagic fish such as non-spawning herring may be frightened by the noise and vibration of the vessel and then descend some distance. To then tow the trawl some metres deeper than the fish had been recorded under the vessel, was not always successful.

The decisive breakthrough came with the netsonde, i.e. a headline transducer connected by a special cable ("third wire system") to an echo sounder recorder in the wheelhouse of the trawler. The present netsonde cable has a breaking load up to 1.5 t. For smaller vessels the connecting cable has to withstand a tension of at least 700 kgf (Takayama and Koyama, 1961). For cable lengths of more than about 500 m a special semi-automatic power driven winch is needed while shorter lengths can be operated with a hand winch. It has been proposed that the cable should be reinforced by attaching a light pre-stretched Terylene rope (Carpenter, 1968).

With the echo sounding netsonde, in addition to the distance of the trawl from the bottom or the surface, the vertical opening of the trawl is indicated so that the correct behaviour of the gear can be judged. The decisive superiority of this system is the recording of fish in and around the net opening which enables optimal aiming of the trawl, and also an approximate estimate of the amount of catch (Schärfe, 1966).

The idea to use an echo sounder with headline transducer(s) is more than twenty years old, but as far as is known this was not used in commercial fishing before the end of 1958. Since then it has been firmly established by practical experience that in midwater trawling "working without one is like using a butterfly net with your eyes shut", as Ronnie Balls said originally of the echo sounder.

Originally the netsonde sounded downwards only. When fishing over extreme depths of 1,000 m and more the recording of the seabed may become inconvenient and this led to the "up/down" netsonde which is used by commercial trawlers since 1967. It has one upwards and one downwards directed transducer in the same casing which can be switched alternately from the recorder unit in the wheelhouse (N.N., 1969d). Previously the single netsonde transducer was turned upwards and even shifted to the footrope to measure the net depth with reference to the better reflecting surface. By removing the upper sound shielding, simultaneous up/down sounding with one transducer was utilized, also by commercial trawlers. Another system employed one down transducer in combination with another one directed forward (Szatybelko, 1962). Later on more transducers were combined, facing in different directions, e.g. from the headline up, down and forward and from the wingtip across and outwards. This multi-netsonde equipment was first developed for the development of midwater trawl gear and techniques (Schärfe, 1966d). It was eventually also utilized for the observation of fish behaviour only (Mohr, 1967; Margetts, 1967; Hartung, 1968) for which special devices with 4 to 12 transducers sounding in various directions around the net opening have also been designed. By now, commercial multi-netsonde equipment is available with two transducers (up/down) and four transducers (up/down and two ahead) to which a temperature telemeter, an amount-of-catch meter and other instruments can be attached.

Since netsonde cable is expensive, and requires an additional winch and may also cause some troubles to inexperienced operators, wireless communication has been developed. The former mere depth telemeters have meanwhile been followed up by real wireless echo sounding netsonde devices. The acoustic signals from the net unit are received by a hydrophone installed in a paravane which is trailed at about 70 m cable aside and behind the trawler. The display on the recorder in the

wheelhouse shows the ground, the surface and fish entering or passing the trawl similar to the cable netsonde (N.N., 1969b; Holme and Mills, 1969).

Net materials for midwater trawls

While echo sounding is certainly one prerequisite of midwater trawling, another one, at least for larger trawls, is the material for the netting (see v. Brandt and Klust, 1970).

The main requirements are—high tenacity, particularly good wet-knot breaking strength and high extension and elasticity for compensating differences in the distribution of the load in the forenet to reduce the danger of bursting under shock loads in heavy sea which are best met by polyamide net yarns. For small one-boat midwater trawls towed at slow speed under predominantly good sea conditions, other synthetic fibres, e.g. polyethylene, are sufficient. The netting is mostly knotted. Knotless netting for instance is used in midwater trawls for shrimp N. N., 1963).

Principal types of one-boat midwater trawls

Although there are many written accounts of one-boat midwater trawling, written by scientists, skippers, etc., only a small number of comprehensive reports are available, such as: Canada: Barraclough and Johnson, 1960; Johnson, 1968; France: Nédélec, 1962; Nédélec, 1966; Germany (Fed. Rep.): v. Brandt, Schärfe and Steinberg, 1960; Schärfe, 1969b; Japan: Hamuro and Ishii, 1961; Poland: Okonski, 1964; Sweden: Johansson and Lindquist, 1967; U.S.A: McNeely, 1963, 1964; McNeely, Johnson and Gill, 1965.

There are true midwater trawls which would be damaged when touching bottom, "multi-purpose" or "universal" trawls which can be used for midwater and bottom trawling and finally "semi-pelagic" trawls the otter boards of which are towed on the ground while the net keeps some distance.

The prototype of the two-boat midwater trawl was the stownet made off our panels. The German experiments with one-boat midwater trawls originated from the conventional bottom trawl made of an upper and a lower panel. In the beginning two-panel trawls were considered more suitable. The German experiments with four-panel trawls began in the autumn of 1962. Nowadays most of the one-boat midwater trawls are of four panels design. The panels can be equal, but mostly the side panels are narrower than the top and bottom panels and the bottom panels can have longer wings than top panels. In this case, the side panels have wings of different length. The mesh size especially in the forepart of the trawl was made very large to reduce the drag of the gear. For the same purpose it has also been proposed to have small meshed netting for top and bottom panels and large meshes for the side panels (Hamuro and Ishii, 1961).

As far as is known, there is only one midwater trawl for single boats with more than four wings, which had some commercial success. This is the Swedish six wing net by Steiner Persson (Larsson, 1959). This net is used now in the Baltic for catching small herring. In comparison with the original model, the mesh size in the anterior part of the trawl was increased and the bridles lengthened.* The size of the midwater trawls is usually indicated not by the length of the footrope and/or the headline, as is common for bottom trawls, but by the circumference in number of meshes at the seam between wings and body. Trawls of the same mesh size (e.g. mesh length 200 mm = ca 8 in) are easy to compare. After the mesh size in the front part was considerably increased (to reduce towing resistance) the mesh size has to be considered as well, e.g. a trawl with 800 meshes circumference and 500 mm stretched mesh corresponds to a trawl with 2,000 meshes circumference and 200 mm stretched mesh.

With increasing net mouth area also the catching efficiency of midwater trawls increases (Schärfe, 1969b). During the German midwater trawl developments the net opening was increased from 250 m^2 (two panel nets with 200 mm stretched mesh and 700 meshes circumference) to more than 2,000 m^2 (four panel nets with 560 mm stretched mesh, 1,114 meshes circumference which corresponds to 3,100 meshes circumference of 200 mm stretched mesh, since 1967). The reason for this was the netsonde observation that many fish normally keep in the opening an escape distance of some metres from the framing lines and the netting (e.g. non spawning herring 3 to 8 m). It seems that the escape distance between fishes and netting is influenced by the towing speed and that it decreases with towing speed (Fischer and Posselt, 1968).

For catching large rapid-swimming fish in quantity, extremely large nets pulled at relatively low speed are more effective than smaller nets pulled at higher speed. In this case the fish would be caught by the trawl before it could sense its presence (Alverson, 1962).

The demand for a maximum possible net opening size leads not only to a large net but also to respectively large towing power. For big vessels the high price of such large midwater trawls may become a real limitation. For smaller vessels the main limitation is the towing power and the power of the winch. Therefore many experiments have been done to decrease the drag of a trawl gear by increased mesh size in the forenet, by using thin twines and, last but not least, by employing otter boards of high hydrofoil performance. Some examples are given in Table 1.

In this table most trawls are four panel one-boat midwater trawls. The circumference is given corresponding to 200 mm mesh size stretched (data for more than 1,000 meshes are rounded off). The weights on the groundrope and the buoyancy of the floats of the headline were calculated in kg. The front weights directly on the top of the wings or in some metres distance are calculated in kg (rounded off).

Otter boards for one-boat midwater trawls

Originally, common flat bottom trawling otter boards were also used for midwater trawling. Today, boards of conventional type, rectangular or oval, are used for small midwater trawls only (e.g. Johansson and Lindquist, 1967). Depth recorders demonstrated that the boards were rather stable during towing, but it was also found that this was due to the stability of the trawl net.

* According to information kindly given by Mr. Otterlind in Lysekil, Sweden.

TABLE 1.

Country	Circ. in 200 mm meshes	True mesh size in forenet mm	Ground rope weights app. kg.	Buoyancy of head-line floats app. kg.f.	Front weights app. kg	Bridles length m	Trawlboards area · m² each	Main species caught	References
Canada									
No. 5 Canadian midwater herring trawl	800	203	45	160–185	70–90	73/74	Süb. 3.0	Herring	Johnson, 1968
France									
Chalut pélagique 44–40	1000	240	15+2×60	150	440	140/144	Süb. 3.2	Herring	Nédélec, 1966
Midwater trawl for 150 hp	496	160				40	Oval	Sprat	Portier, 1970
Midwater trawl for 750 hp	739	160			400	50	Süb. 4.0	Herring	Portier, 1970
Midwater trawl or 1500–1800 hp	1118	200			600–800	80/120	Süb. 6–8	Cod	Portier, 1970
Germany, Federal Republic	1400	200	150–200	140–185	500	100–150	Süb. 5–6	Herring	
	1600	200	150–200	140–185	500	100–150	Süb. 6–8	Herring, cod	see also
	2000	200/560	200–250	185–350	800	100–200	Süb. 8–12.5	,, ,,	Schärfe
	2200	560	250	185–460	800	100–250	Süb. 8–12.5	,, ,,	1969b
	2700	560	250–350	185–460	1000–1200	150–250	Süb. 8–12.5	,, ,,	Table 3
	3100	560	250–350	185–460	1200	200–250	Süb. 12.5	,, Redfish	
Japan					*Depressors*				
Small boat midwater trawl, 200 hp	503	76	9+2×7.5	35	2×16.5	50/50.5	hydr. 0.84		
Small vessel midwater trawl, 400 hp	528	120	9		2×20.0	70/71	hydr. 1.89	Prawns Croaker Hairtail	Hamuro and
Middle sized vessel midwater trawl, 500 hp	702	121			2×55.0	80/80.8	ca. 2.0	Cod Herring	Ishii 1961
Large vessel midwater trawl, 1200 hp	976	152	27+63	110	2×40.0	101/102	hydr. 3.30		
Sweden									
Persson Stjärntrål (2 seams in aft)	293	85	20	128	0–40	55/92	plain 2.2	Herring Sprat	Johansson and Lindquist 1967
Fotö trawl (2 seams, nowadays also 4 seams)	281–360	85/100	40	120–145	15–40	64/92	plain 2.9 or V-boards		
U.K.									
Boris trawl	235	110	6–12	24+	34	18.5	Süb. 1.36	Sprat	Noel 1966
U.S.A.									
"Cobb" pelagic trawl	900	76		95	—	110	hydr. 3.7	Hake Ocean perch Anchovy	McNeely, Johnson and Gill 1965
B.C.F. Universal Trawl, Mk. II	422	127	120–180	80–155	—	55	V-bd. 5.6	Rockfishes Sole True cod Dogfish Skates	Jurkovich 1968
U.S.S.R.	1540	200	420	400	500		Süb. 8.0	Mackerel Horse-mackerel Bluefish Sardine	N.N. 1970

The depth fluctuations of the boards increased with increased bridle length. Therefore it was proposed (1947) to use boards with better hydrodynamic properties. Since 1949 hydrofoil otter boards designed by F. Süberkrüb have been used in German trials. Süberkrüb made his first experiments with models of midwater trawls in 1937 and 1938. The compound wood and steel structure of the Süberkrüb trawl boards was later replaced by full steel construction.

Unlike otter boards for bottom trawling, for midwater trawling the sheering force of the otter boards should not be directed slightly downwards but horizontal or even slightly upwards (Süberkrüb, 1957). The Süberkrüb type boards have this feature. The better performance of curved boards of this type is mainly due to their lower drag, but the sheering efficiency is also better than that for flat boards. The lower width to height ratio of about 1:2 is also advantageous. With increasing size of trawl nets, front weights and bridles also, the otter boards had to be increased (Table 1). Other hydrodynamic otter board types are the Swedish wing boards which were specially developed for one-boat midwater trawling in

1957 (Larsson, 1959). They resemble aeroplane wings, with a plane pressure surface and curved back.

To achieve an effective well-shaped net opening, it was proposed to use four otter boards (v. Eitzen, 1957; McNeely, 1959; Balls, 1960; Alverson, 1962). For the Cobb pelagic trawl originally two Larsson otter boards were attached to the lower bridles, and two other aeroplane-wing-like hydrofoil doors to the upper bridles. It was reasoned that a four otter board and bridle system would be more effective in opening the mouth of the trawl than the conventional dual otter board system requiring longer bridles and larger doors (McNeely, 1959). Nevertheless, today predominantly two otter boards are used mainly for technical reasons. The idea to suspend otter boards on long pennants has also been abandoned. This rig, with up to 10 fm long pennants, was characteristic of the original British Columbia midwater trawl (Barraclough and Johnson, 1955a).

Aeroplane wing-shaped otter boards but not tapered in diameter like the Swedish ones are also known. The Cobb otter board is also higher than broad and has in its upper end trawl floats to keep it upright in the water (McNeely, Johnson and Gill, 1965).

Japanese boards are curved, but often wider than high: Clark Yacrofoil (Hamuro and Ishii, 1961). A special type has a small curve at the rear which serves as a rudder and provides an adequate attack angle when towed (Kobayashi and Inoue, 1960). Such boards arbitrarily supposed not to rise or sink, and with the centre of gravity close to the lower edge will normally assume proper position when set. There may, however, be some doubts as to whether such complicated boards are suitable for commercial sea fishing.

Originally, the hydrofoil otter boards for midwater trawls were not designed to be towed along the bottom. Therefore with the trend to develop "multi-purpose" trawls also dual purpose otter boards were proposed. V-shaped otter boards are known for good stability even when touching rough bottom (Hoheisel, 1970). Special types with improved horizontal stability by the provision of two horizontal stabilizing fins were constructed (Barraclough and Johnson, 1960). These fins served to minimize oscillatory movements. An air ballast tube on the upper edge and a runner (shoe) with lead ballast on the lower edge increased vertical stability.

Oval otter boards are also used for combination midwater and bottom trawling and types are proposed which are not flat but concave. The French offer such boards named "Panneau de chalut polyvalent" (N.N., 1969a).

Finally, steerable and motor driven otter boards have to be mentioned. It has been proposed to control the depth of a midwater trawl not by length of warps and/or speed of towing but by guiding the trawl with the help of aeroplane-like devices, whose depth is regulated by air pressure (Cooke, 1960). A twin otter board with an electrically rotated cylinder has also been proposed. The principle employed is the same as in the Flettner hydroplane proposal of the 1930's (N.N., 1968b). The rotor action forces the twin board into a dive or a climb, depending on the direction of rotation. There is some doubt as to whether such devices are not too complicated, expensive and sensitive for reliable operation on commercial trawlers (Schärfe, 1966c). This may also apply to otter boards of too sophisticated construction. In 1965 such otter boards for midwater trawling were demonstrated at a fishery exhibition in Göteborg, Sweden, which had tube shape of which a jet effect increasing the sheering power was expected.

Sheering devices

To keep the opening of midwater trawls in the most effective form not only trawl boards are needed but also floats on the headline and weights on the footrope at the lower wing tips and also front weights. The force required to open the trawl vertically is especially induced by the front weights at the lower wing tips. Midwater trawls, in contrast to bottom trawls, thus open downwards and not only upwards (Schärfe, 1969b).

Floats have constant buoyancy but the inherent disadvantage of increasing towing resistance with increasing speed. Consequently, with increasing towing speed the vertical opening of the trawl decreases. To avoid this disadvantage, an effort was made to replace floats and weights by hydrodynamic elevators and depressors, the sheer of which changes with speed the same as resistance They should therefore be even more efficient than floats and weights, especially at speeds between 1.5 to 3 kn (N.N., 1958).

In some experiments spherical floats with sheering devices or kites combined with floats were used. Well known examples are the English profiled, kite-type floats and the French "Exozet" kite. For the Swedish Fantomtrawl "trawl toads" were designed wich adjust themselves automatically to the best working position. These "elevator toads" which like the Danish "Trawlspileren" take the place of the customary floats along the headline, can be used also to replace the weights of the footrope in the form of "depressor toads". In this form the trawl toads are still offered today (Garner, 1966). Canadian hydroplane, kite-type floats were used for the midwater trawls (Barraclough and Johnson, 1960; Ronayne, 1960). Similar types were used also in the first German experiments (v. Brandt, Schärfe and Steinberg, 1960). Later on, model tests showed that kites are almost useless for normal midwater trawls because of the high load acting on the headline (Schärfe, 1966b). They are of interest only when trawling near the bottom with diminished influence of the front weights touching the bottom or for trawling near the surface when part of the load is taken off the headline by modifying the rig.

Depressors which can take the gear down without heavy sinkers seem to have gained more importance. Such devices which could slide freely on the sweeplines to replace the heavy front weights were first used in the Canadian experiments (Barraclough and Johnson, 1955b). Many experiments with depressors have been made by Hamuro and Ishii (1961) who tried them not only in place of the front weights but also on the middle of the footrope to increase the sinking speed. The biggest specimen had a weight of 80 kg in air.

One of the purposes mentioned for the Swedish trawl toads was to bring the trawl deeper than the otter boards which were expected to frighten the fish from entering the net.

Unfortunately, elevators and depressors are mostly

rather complicated and therefore expensive. They are also more difficult to handle than floats and weights, especially when shooting and hauling the gear. Therefore, in spite of their unquestioned advantages, with the exception of flat kites, elevators and depressors are hardly used in commercial fishing.

It should be mentioned that it was also attempted to produce favourable sheering forces by specific net design. For example, in some four panel trawl nets the lower panel is made longer to obtain some downward sheer. Recently a four panel version of the Swedish Fotö trawl (Table 1) was provided with two sections of small mesh netting between the upper and lower wings to act as kites, and thus increase the vertical opening. This is quite in contrast with the tendency to enlarge the mesh size in the front part of midwater trawls to reduce towing resistance.

Multi-purpose and semi-pelagic trawls

Pelagic trawls are not meant to replace bottom trawls. They are considered an additional fishing method to be used as circumstances demand.

When midwater trawls incidentally or purposely touched the bottom the netting and even the otter boards were easily damaged (Barraclough and Needler, 1959). Also long bridles and legs were sometimes caught by obstructions, pulling the headline down and damaging the netting (N.N., 1965b). To be capable of trawling on the bottom and in midwater without this difficulty, special multi-purpose (universal) trawls were constructed. The netting was made stronger and bobbins and/or dropper chains were added. Otter boards similar to conventional ones were chosen and such dual-purpose otter boards facilitated also quick changes from midwater trawling to bottom trawling and vice versa (Barraclough and Needler, 1959). The bridles were altered in a manner allowing the net to float higher than the otter boards (N.N., 1965b). These new modifications were intended not only for bottom and midwater trawling but also, with extended wings, for Danish seining (N.N., 1968a).

A new American proposal suggests a universal trawl with multi-bridles (McNeely, 1968). The observation that sometimes fish are distributed in a horizontal layer over a distance of a mile or more but rarely more than 30 ft thick has stimulated considerable interest in extending the horizontal opening of the net. To avoid the vertical collapse of the trawl with increased speed, one extra bridle was attached to the centre of the footrope and the centre of the headline. This is reminiscent of the "Lozenge trawls" (Hu, 1965; Garner, 1965; N.N., 1967) which is meant to be used both in midwater and on the bottom.

In a French proposal for multi-purpose trawls additional panels ("pilots") as stabilizers should give the otter boards an increased tendency to plunge, which, combined with the original weight of the board brings the net rapidly to the desired depth. In contrast to usual midwater trawl the warps should not be longer than those used for ordinary bottom trawls (Grouselle, 1959; N.N., 1961d; N.N., 1962a). Most of the tested multi-purpose gear was not so complicated (Schärfe, 1966b). Even the flat otter boards with four panel trawls were used with success as multi-purpose trawls (Okonski, 1964; Table 1).

There are some reports on successful catches with multi-purpose trawls (e.g. Tiews, 1964; N.N., 1965c; Jurkovich, 1968) and shrimps (N.N., 1963). Other often unpublished experiments have been less successful. There are therefore some doubts as to whether the multi-purpose trawl concept is the best solution, or if both types, bottom trawls and midwater trawls, are needed. Garner (1965) has said some years ago: "If multi-purpose trawls can show fairly similar results as bottom trawls or pelagic trawls, then obviously the dual purpose trawl would be the answer". But other people think that two special trawls are needed for bottom and midwater trawling and that the solution is not a multi-purpose trawl but better deck arrangements for a quicker exchange of the two trawl types when needed.

Midwater trawls and multi-purpose trawls can be operated easily at almost any depth. Often trawls are wanted for fishing a small distance from the bottom only. Special "semi-pelagic trawls" with conventional rectangular or oval otter boards linked to the lower bridles have been developed. The otter boards travel on the ground and the footrope of the net some distance above. The Icelandic Breidfjörd trawl is an example of a midwater trawl mostly used in semi-pelagic trawling for cod (Parrish, 1959).

Such trawls with otter boards sweeping the bottom and a net floating 0.5 m (N.N., 1961e) or 9 m off the bottom (N.N., 1961a) have been tested successfully. In the United States also the "Cobb" pelagic trawl has been rigged to fish just off bottom. For the same purpose a "lampara trawl" with very long wings was designed to fish hake between 4 and 7 m off the bottom with otter boards in contact with the sea bed, but this lampara trawl caught less than the Cobb pelagic trawl (N.N., 1965a).

Especially French trawlers had good catches of semi-pelagic cod and herring, staying not too far off the bottom. Strictly speaking, the French "chalut semi-pélagique" is however not a midwater nor a semi-pelagic trawl, but a high opening bottom trawl (Thorsteinsson, 1965). The trawl is towed on the bottom, but the rigging, especially the bridles, is the same as the Breidfjörd trawl (Libert and Nédélec, 1966). The trawl operates as a bottom net, but the fish caught are semi-pelagic. Real semi-pelagic trawls are the link between midwater and high opening bottom trawls.

Future trends

For rational midwater trawling the term "aimed trawling" was introduced to indicate that with the help of the ship's sonar and echo sounder and the netsonde on the headline of the trawl, much more exact operation of the net with regard to the fish is possible (v. Brandt, Schärfe and Steinberg, 1960). According to Kajewski (1960) similar ideas and definitions have been developed by scientists in the U.S.S.R. since 1949.

Aimed midwater trawling is continuously being improved by further developing design and operation of the hydroacoustic equipment (Gaede, 1964) and by increasing the size of nets, otter boards, weights and bridles (Schärfe, 1969b).

Studies of fish behaviour with regard to the gear for better fishing tactics receive increasing attention.

Decreasing stocks need more precise operation of the gear and observations of the fish to be caught. The operation of the larger gear requires more power and echosounding techniques become more and more sophisticated. Moreover, manpower becomes expensive and in some highly developed industrialized countries difficult to get on fishing vessels. The possibilities for mechanization are limited and therefore the question arises as to how automation can help to save manpower, to reduce the workload and to improve the efficiency of the skipper. Is computer trawling possible? When a school of fish has been detected by sonar scientists from the U.S.S.R. want to feed the signals from the sonar and sounding devices directly into a computer which calculates direction and speed of the school and the point of interception with the net (N.N., 1962b). The computer further will instruct steering gear and main engine to bring the vessel with the trawl in the best position, or winches and other auxiliaries to shoot the trawl automatically. It will also bring and keep the midwater trawl in the right depth by automatically controlling warp length and towing speed. Even the quantity of the catch will be monitored and the time of hauling determined automatically.

The realization of automated midwater trawling will, for instance, need more efficient hydroacoustic gear to select the most profitable fish schools. Gear improvements will be needed for better guiding of the fish into the trawls. More efficient handling of the trawl gear will require modifications in the vessel design and naval architects will have to cooperate. The exchange of trawls has to be accelerated to reduce non-fishing time. It is well known from midwater trawling that some times high catches can be made during only a few hours of the day. In this time the fish schools must be worked intensively before they are broken up or lost. It has therefore been proposed to use two trawls alternatively—hauling one and immediately shooting the other. Studies of twin trawl operation have been carried out in the U.S.S.R., Poland and the German Democratic Republic (N.N., 1969c). Proposals have also been made for automated trawl hauling, i.e. shooting and hauling (Birkhoff, 1966). Fishing gear technologists will need more and more the cooperation of naval architects and engineers familiar with electronic problems regarding fishing gear, steering systems and computers.

Reduction of working hands by automation is a general trend not only in fishing. It seems that especially one-boat midwater trawling with large stern trawlers is well suited for computer automated fishing.

References

The author is willing to provide an extensive list of references upon application (see List of Contributors for address).

Trawling Gear in Japan

M. Nakamura

Les chaluts au Japon

Les chaluts japonais sont fabriqués en filets sans noeuds (type câblé) ou noués (noeud de tisserand). Le matériau principal est le polyéthylène. Des essais sur maquettes ont été utilisés sur une grande échelle pour la mise au point des chaluts. On a découvert que les chaluts à deux faces n'avaient pas un contact avec le fond satisfaisant. Ceci est à l'origine de l'introduction des filets à quatre et six faces, qui fournissent en même temps une plus grande hauteur d'ouverture. Des plateaux élévateurs sont d'un emploi généralisé pour l'obtention d'un gain plus marqué de hauteur d'ouverture, laquelle est également améliorée par des barrettes. Dans le but d'augmenter la dimension de l'ouverture, on a essayé des filets "doubles" constitués de deux corps de filets disposés soit l'un à côté de l'autre pour une augmentation de largeur, soit l'un sur l'autre pour accroître la hauteur. Des tentatives ont été faites en vue de la mise au point d'un chalut combiné pour la pêche au fond et entre deux eaux. Un équipement de netzsonde sans câble remplace le modèle avec câble. L'emploi continu du sonar, de l'échosondeur et du netzsonde est courant, à la fois avec les chaluts de fond à grande ouverture et pour le "chalutage par bonds", c'est à dire le chalutage sur le fond où à une certaine distance de celui-ci en fonction de la répartition du poisson. Les panneaux divergents plats ont été abandonnés à l'exception du chalutage de la crevette avec un gréement double. Il en est de même pour les panneaux plats de forme ovale ou ovoïde qui, bien que fournissant des performances légèrement supérieures, ne sont plus en usage au bout de seulement six mois environ. Le modèle qui prédomine actuellement est le panneau hydrodynamique incurvé dont les performances en fonctionnement ont été améliorées par l'abaissement du centre de gravité et par l'adjonction d'une flottabilité dans la partie supérieure pour réduire le risque de voir ces panneaux tomber à plat dans les changements de cap accentués. On utilise aussi une forme hydrodynamique pour les pateaux élévateurs.

Equipo para la pesca de arrastre en el Japón

Los artes de arrastre que se hacen en el Japón son de mallas sin nudo (hilos colchados) o con nudo (nudo llano), empleándose en su fabricación principalmente el polietileno. Se han hecho muchos ensayos de modelos para perfeccionarlos. Los artes de dos paños no se pegaban bien al fondo, por lo que empezaron a emplearse de cuatro y seis paños que, al mismo tiempo, dan más altura a la boca. En general se usan planos elevadores para incrementar la altura de la relinga, a la que también sustentan ligadas de refuerzo. Para incrementar la abertura se han empleado redes dobles formadas por dos casaretes que se ponen juntos para ganar anchura o uno encima del otro para ganar altura. Se trata de construir un arte combinado para pescar en el fondo y entre dos aguas. Las sondas inalámbricas que se montan en la red sustituyen a las que tienen cables. El empleo de sonar, ecosondas y sondas montadas es también usual con el arte de fondo de mucha abertura y para pescar "a saltos" es decir arrastrar por el fondo y encima de éste, según la distribución de los peces. Ya no se emplean puertas planas, excepto en la pesca del camerón con arte doble. También han dejado de usarse, después de medio año, aproximadamente, las puertas ovaladas planas cuyo rendimiento es poco mejor. En la actualidad predominan las puertas curvadas de forma hidrodinámica cuyo rendimiento se mejoró bajando el centro de gravedad y dándoles flotabilidad en su parte superior, par reducir el riesgo de que cayeran en las viradas cerradas. También los panlos elevadores son de formas hidrodinámicas.

JAPANESE trawlnets are mostly made of 380 or 400 denier polyethylene (PE) resin and processed by the low/medium pressure method. Both English knot netting and Japanese type knotless netting are used.

Strength of polyethylene filament is:

at linearity: approx 5 g/d. Breaking elongation about 20 per cent

at loop: approx 4 g/d. Breaking elongation about 10 per cent.

Polyethylene is cheapest among all synthetic fibres produced in Japan and as it has optimum stiffness it is easy to handle, and is the most economical to use in all respects.

Polyamide (PA) such as nylon is expensive and as it is too soft, tends to hang-up on shackles and other hardware. Due to heavy water absorption, and becoming fluffy after abrasion, the crews of trawlers complain of difficulty in handling nets made of nylon. Although nylon can be treated with resin to minimize such faults, it is inadvisable considering cost. Polyethylene, when processed by the high pressure method, is not at all suitable for trawl net material since it is too weak, lacks stiffness, and is apt to be worn away by abrasion.

Japanese type knotless netting has less towing resistance than knotted netting (fig 1) thus permitting trawling with a larger net area. Therefore, knotless netting is widely used for trawling on smooth bottom. Since knotless netting is more difficult to repair than knotted netting the latter is preferred for rough ground.

There are a considerable number of trawlnets composed of both knotless and knotted nettings, the knotless nettings being used for square and baitings where the risk of damage is less and the knotted netting for other parts such as wings, belly, codend, etc.

Both knotless and knotted netting is treated with heat setting after manufacture to orientate distortion or uneveness of filaments, to thin the diameter of twine and to stabilize the shape of meshes.

The laboratory of the Nippon Gyomo Sengu Kaisha, Ltd. has a water tank for testing model trawl nets (fig 2) which is 100 m long, 5 m wide and 1.5 m deep. It has a bridge-type towing carriage with an adjustable speed from 0.5 to 5 kn.

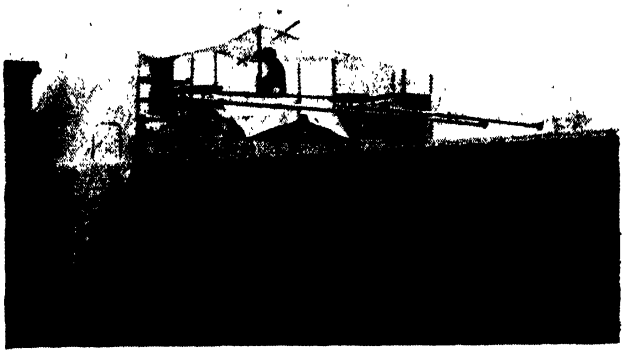

Fig 2. Model test tank

On one side of the tank, there are windows so that trawling conditions during model tests can be observed. By mounting an underwater camera in front of the test net, a frontal view can be taken. Model scales of 1:3 to 1:15 are common for trawlnets and scales of 1:5 to 1:25 for complete trawl gears.

Types of trawlnets

Many different types of bottom trawls are used depending on the species of fish to be caught and the condition of the sea bed.

To trawl fish close to sea bottom

As the horizontal opening of the net is more important than the opening height low-opening two-seam, four-seam and two-body trawlnets are commonly used.

Two-seam trawlnet—This net type (fig 3) which is common in Europe, is used by a few vessels in Japan as the groundrope does not maintain good contact with the bottom throughout its entire length. The groundrope bosom corners have a tendency to lift off the bottom allowing fish to escape.

Four-seam trawlnet—According to the size of side panels the shape of the net's mouth can be adjusted to "flat".

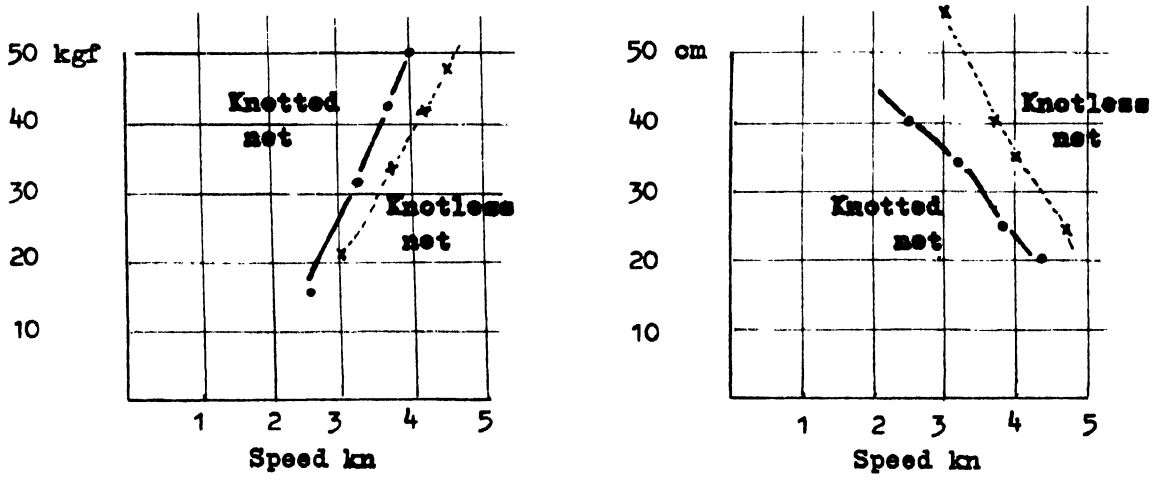

Fig 1. Towing resistance (left) and opening height (right) of trawl models scale 1:10 made of knotted and knotless netting

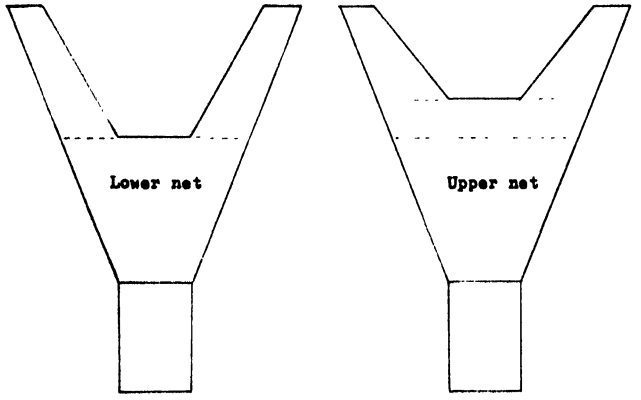

Fig 3. Scheme of two-seam bottom trawlnet

"semi-ballon" and "ballon", (fig 4). Thus, when aiming for a wide opening (flat) of the net mouth the side panels of the four-seam trawlnet are made narrower. The four-seam trawlnet has four riblines and proper "hang-in" of the netting to these lines is important to enable easy opening of the meshes. This type of net is used by a great number of vessels as it is much easier to repair than the six-seam trawlnet (described later).

Twin-body trawlnet—When aiming at an extra wide opening of the netmouth, the twin-body trawlnet is used in Japan (two small trawlnets are put side by side, the inner wings are removed and both nets are connected in parallel) (fig 5).

When the one-body and twin-body trawlnets are made with identical flow resistance, the latter opens about 30 per cent wider than the former. The angles of the netting in the wings and body against the water stream are smaller resulting in reduced meshing of fish. Because of its good efficiency a considerable number of vessels are using this type of net.

The two bodies of this trawlnet are optionally adjustable for connection at the first of the bellies or midway

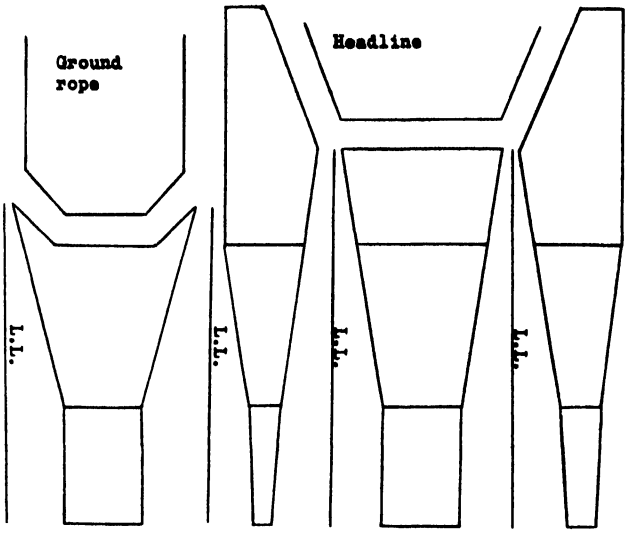

Fig 4. Scheme of four-seam bottom trawlnet

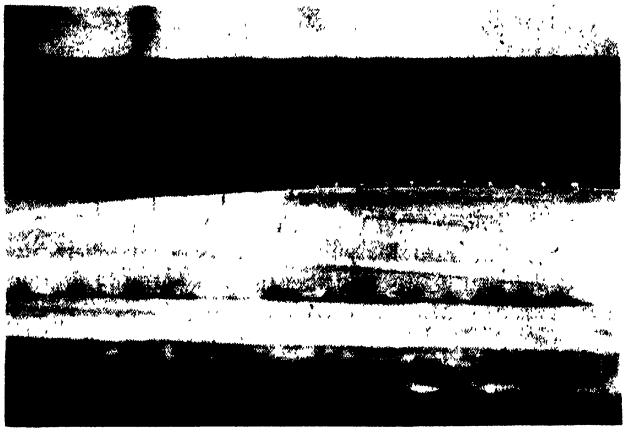

Fig 5. Twin body model net

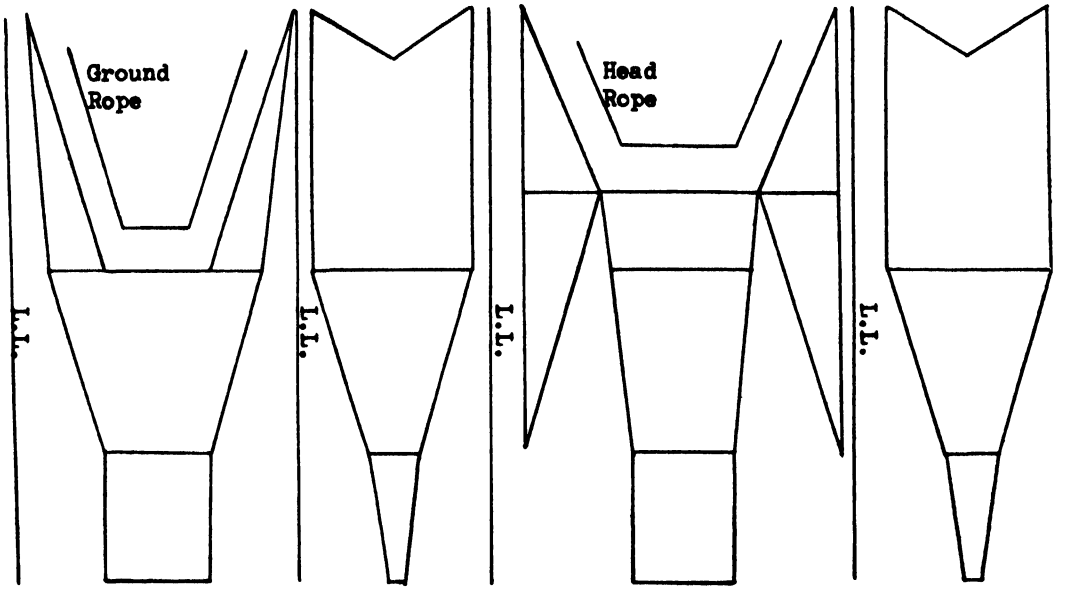

Fig 6. Scheme of six-seam high opening bottom trawlnet

between the codends and the front of the bellies. When fishing with sterntrawlers, equal catches of fish can be expected in both codends (although an unbalanced catch may also occur), while for side trawlers unequal catches are common.

Shooting and hauling of the twin-body trawlnet on a sterntrawler is the same as for normal trawls and does not need any special technique.

To trawl fish swimming several metres off the bottom

A wide opening of the net mouth is necessary but on some occasions, if the net mouth is opened not high enough, the net may catch only part of a fish school, or may even be trawled below the school. By sacrificing to some extent the opening width of net a high opening can be obtained. For this purpose, in Japan, the four seam trawlnet with large side panels or the six-seam trawlnet are mainly used. In addition, to gain extra height, a vertical twin-body net is undergoing study.

Six-seam trawlnet—This is an improved four-seam trawlnet having wide side panels (fig 6) designed so that the net mouth will be almost round (Balloon).

The riblines are geometrically arranged so as to lessen, as much as possible, the force on the head rope and to open the net high using the lifting force of the upper sections of the net.

By modifying the width of the section or panels, a trawlnet with an oval cross section can be achieved.

There are a large number of two-boat trawlers operating in the East China Sea with a net opening as high as twenty metres.

Two-floor trawlnet (Vertical twin-body net)—On the two-floor trawlnet the bodies are vertically connected (fig 7). Its purposes are to aim at a high opening of the net mouth, but it is also used to separate fish. Fish such as sole, swimming close to the sea bottom are caught with the lower net and fish such as herring swimming off the sea bottom are caught with the upper net making separation of fish easy when hauled on board. On unknown fishing grounds, this type of net can be used as a test net to determine the required height of the net mouth. Advantages in actual fishing operations are now under study.

Fig 7. Vertical twin body model net

To trawl fish over the sea bottom

Fish swimming close to the bottom tend to escape to the right, left or upward when they sense the net coming close. The bottom trawlnet checks the right-left escape of fish with both wings while the upward escape is checked with the square. Fish swimming off the bottom escape in all directions when the net comes close to them. Therefore, it is thought rational to use the same shape of netting for left/right and up/down movement. This is more or less the basic idea in designing midwater trawlnets.

There are many species of fish that swim close to the sea bottom during daytime and at night come closer to the surface and go down again as it becomes light. When trawling for such fish, it is troublesome to change from one type of net to another. Therefore, if it is intended to trawl for such species of fish with only one type of net, it is essential to design a net in between a bottom trawl and midwater trawl. The type of net that meets this requirement is the "hop trawl" net (fig 8). This type of trawlnet has short wings and has the same pattern in the upper and lower sections.

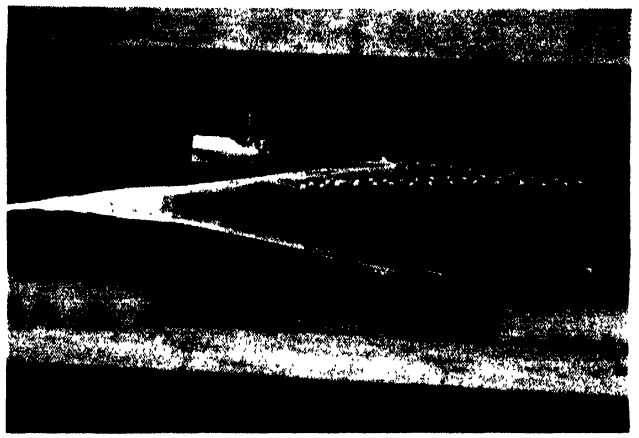

Fig 8. "Hop trawl" model net

"Hop trawling" and midwater trawling

For these types of fishing, it is necessary to be equipped with a netsonde on the centre of the headline, which measures the height of net mouth and distance from the sea bottom and transmits this information to the recorder installed on board the vessel. Formerly, a wire system was used but as operation of this wire is rather complicated, a wire-less netsonde is commonly used at present.

Hop trawling—When a school of fish is detected slightly offbottom (assuming the fish are stationary), the depth of the net must be adjusted by the time it reaches the school.

There are two methods of adjusting the depth of trawl net: one is to wind in the towing warps and the other is to bring the net up by increasing trawling speed. Since time is rather limited, both methods may be used simultaneously.

This method of trawling is also applicable for preventing damage to the net when encountering obstacles on the sea bottom.

The lowering of the net to the sea bottom is done by decreasing the trawling speed or extending the warp length.

Midwater trawling—Even if the net can be brought down to the required depth after the school of fish has been located by either the fish finder or sonar, the school often escapes in an upward, downward, left or right direction. The direction in which the school will escape, depends on the species of fish. Moreover, it must be borne in mind that even the same species of fish will some times change their movements and habits depending on the depth of water, water temperature and other miscellaneous conditions. Thus, the habits and movements of fish have to be well studied and repeated altering of the net position may be needed to secure success.

The netsonde also shows whether or not there are fish in the net.

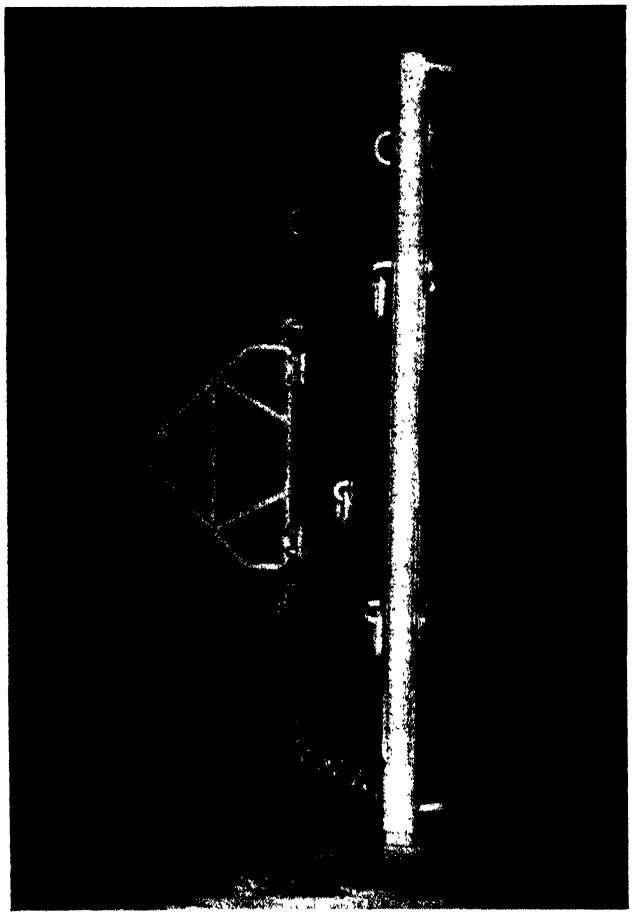

Fig 9. Hydrofoil otter board

Otter board

The common type of flat otter board with small aspect ratio is seldom used in Japan. Reason is that it has a large flow resistance and yet gives less expanding force to the net, and the trawl winch must be repeatedly stopped to open the boards during shooting.

Main type of board used in Japan is a hydrofoil type which has good efficiency for opening the net at low drag and there is no need to stop the trawl winch during shooting. The handling of this type of otter board is comparatively easy after a little experience, and it is widely used by Japanese bottom trawlers (fig 9).

Oval or egg-shaped otter boards which have been developed from the conventional flat otter boards were once used by some vessels. They provide more sheer to the net and have less resistance than the conventional flat type. They are, however, inferior to the hydrofoil type in sheer and drag, and have also operational disadvantages because of which their use was terminated after about half a year.

Model test with flat, oval and hydrofoil type otter boards of the same area (fig 10) gave the results shown in Table 1.

TABLE 1. PERCENTAGE OF WARP TENSION AND WARP DIVERGENCE AT A TRAWLING SPEED OF 3.0 kn

	Flat type	*Oval type*	*Hydrofoil type*
Warp tension	1.0	0.93	0.90
Warp divergence	1.0	1.10	1.25

When observing the otter boards during model tests it was found that:

hydrofoil otter board—is stable, does not stir up sand and causes no eddies at the back of the board

oval otter board—is fairly stable, stirs up sand, and causes slight eddies at the back of the board

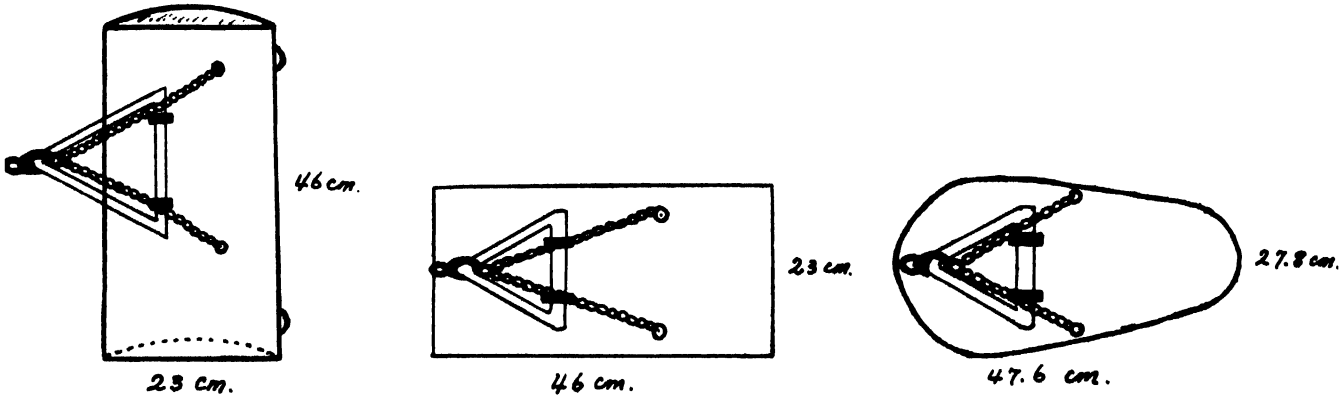

Fig 10. Otter board models scale 1:10

flat otter board—is unstable, stirs up much sand and causes many eddies at the back of the board.

As the hydrofoil otter board has a higher centre of gravity it tends to fall down if trawled at lower speed and when it falls down to the outside, the warp must be partly hauled in to re-set it in its normal position.

To overcome this difficulty the centre of gravity was lowered by attaching a buoyant substance to the upper part of the board. This enabled lowering of the centre of gravity down to about 15–20 per cent from the bottom.

This improved otter board type (called "High Balanced") has been used for the past year with great success and according to reports from the fishing captains using it, the trawling speed can be decreased to 1.0 kn as in the special fishing operation shown in fig 11 without the board falling flat.

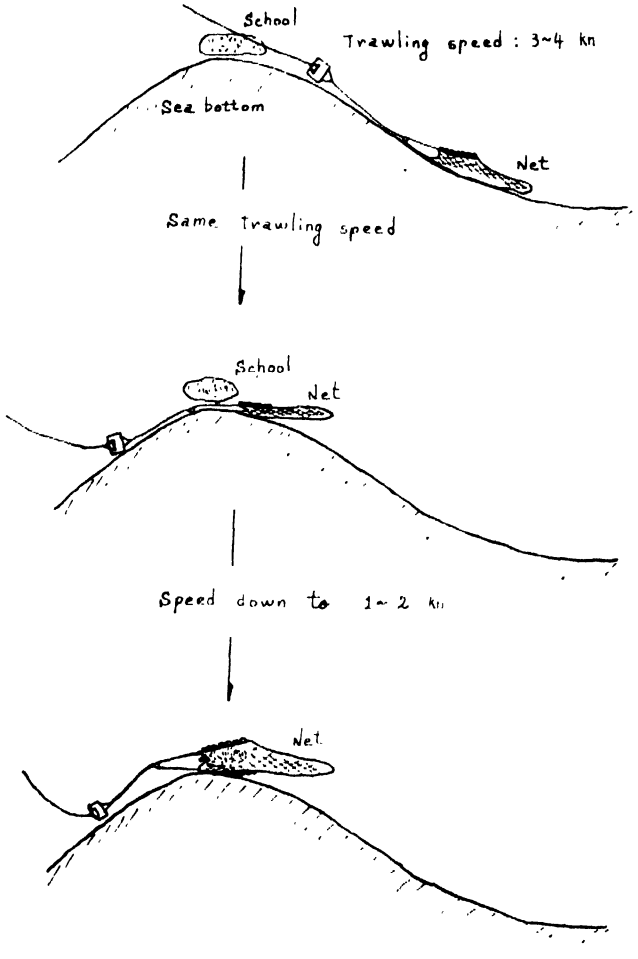

Fig 11. Example of aimed bottom trawling

Floats and kites

Up to about 15 years ago, glass floats of 150–180 mm dia. had been mainly used, but later on a light metal alloy float for deep sea fishing and a synthetic resin float for shallow water fishing came in. The diameter has also become larger over the years. In accordance with the development of synthetic resin, the stronger pressure-proved floats appeared and now the synthetic floats can stand the pressure of 1,500 m depth.

The diameter of floats increased from 240 mm to 300 mm and from 300 mm to 360 mm, these larger floats have a better lift to drag ratio. Since the float is spherically shaped, its buoyancy is proportional to its cubic diameter, while its drag is proportional to the square of its diameter. This means that the larger its diameter, the better its efficiency.

Handling on board the vessel is somewhat limited and improvements have been made through experiment and now 360 mm diameter floats can be used with good results.

As the float is provided with a knob it is not a perfect sphere. Therefore, there is a difference in the drag of the floats as compared with a sphere. Table 2 shows the number and drag of floats of different size with a total buoyancy of 500 kgf. This has been obtained through measurements of buoyancy and drag during trawling with different size floats suitable for 500 m depth.

TABLE 2. NUMBER AND DRAG OF FLOATS WITH TOTAL BUOYANCY OF 500 kgf

Dia. of floats (mm)	150	200	240	300	360
Number of float (p'ces)	370	153	88	46	28
Drag at 3.0 kn (kgf)	1,180	510	310	190	160
Drag at 3.5 kn (kgf)	1,520	660	420	260	210
Drag at 4.0 kn (kgf)	1,960	860	550	340	280

As a lifting device more efficient than floats, kites have been studied, but as they are difficult to handle, they have not been used much in actual fishing until recently.

Meanwhile, hydrofoil kites, which are better to handle, have been developed and are being used for midwater trawling and high opening bottom trawling with good results. At present, more than 100 vessels are using this type of kite, especially with the six-seam trawlnet. It can open the mouth of a net 20–30 per cent higher than ordinary floats.

With two-seam or four-seam trawlnets, kites can not give such efficiency as with the six-seam trawlnets because of the net structure, but still an increase of about 10–15 per cent higher can be obtained. If the efficiency of the kite is further increased, the whole net is lifted and the result is not favourable. Figure 12 shows a model test with a kite fixed on a six-seam trawlnet. As shown in the photo, it is quite a simple thing to attach the

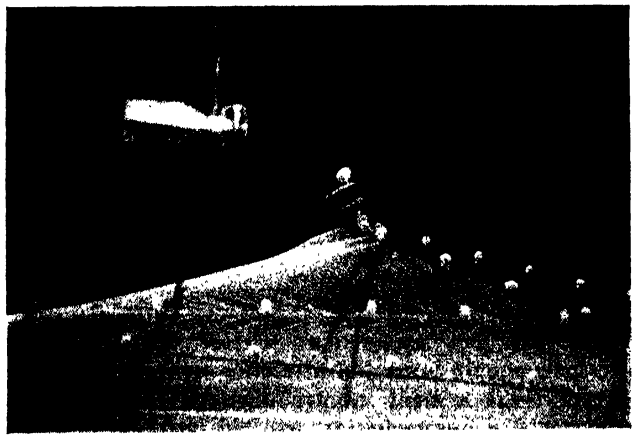

Fig 12. Model kite on model of six-seam trawl

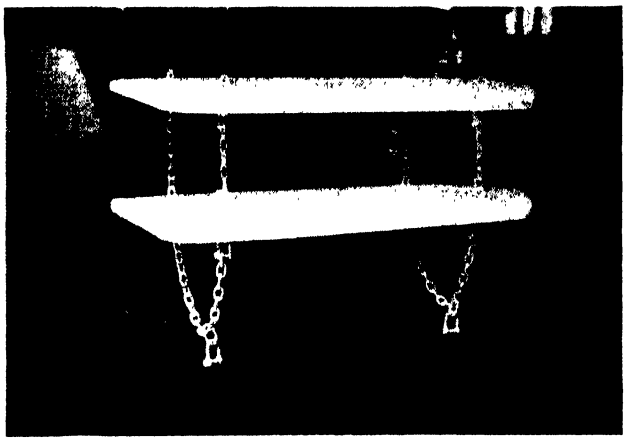

Fig 13. Two wing kite

wing-shape kite at the centre of the headline. The floats on the kite are necessary to keep it in position during shooting. Use of a one-wing kite, two-wing kite (fig 13) or three-wing kite depends on the size of the trawlnet.

The kites are made of synthetic resin foam having a specific gravity of 0.5 and can stand deep sea fishing. The standard size is 1.4 m×0.7 m = 1 m². The lift force of one sheet of this kite is as shown in Table 3.

TABLE 3. LIFT FORCE OF KITE

Speed (kn)	3.0	3.5	4.0	4.5
Lift force (kgf)	145	175	255	320

Ground ropes

Ground rope materials are exactly the same as those used in Europe. For rough bottom iron bobbins of up to 530 mm diameter have been used. Since normally the bobbins are arranged with wider spacing a smaller number is used than in Europe.

The hard iron bobbins may damage the working deck of the trawler, and especially on stern trawlers the net may get between the bobbins and deck and become damaged. To prevent this, rubber bobbins have come into use although they are inferior in durability to iron bobbins. It has been found that by inserting synthetic filaments inside the rubber as in automobile tyres, the service life can be extended.

Un Chalut de Fond à Grande Ouverture pour la Pêche Côtière

C. Nédélec

A high opening bottom trawl for inshore fisheries

During the last few years a new type of high opening bottom trawl has developed in the Boulogne region, where most of the trawlers composing the inshore fishing fleet are now equiped with this gear, which is also spreading to other fishing harbours of the Channel. Derived from the semi-pelagic trawl introduced in France in 1961, this gear is characterized by simplicity, easy adjustment and sturdiness. It differs clearly from the mackerel trawl, another type of semi-pelagic trawl. On each side, the rigging is composed of three bridles a danleno and a sweep line. The performance of the net and its rigging have been observed on models in a special test tank. This type of gear is used by boats of 13 to 20 m and 150 to 400 hp. Most of them are side-trawlers, but with an increasing proportion of sterntrawlers. In comparison with the traditional bottom trawl, the high opening trawl has a better efficiency, in particular for fish species swimming at some distance from the bottom such as whiting and cod. Its development has brought up two facts: (1) the adaptation of trawls to local conditions is a must, and (2) close cooperation between fishermen and gear technologists is very profitable.

Arte de arrastre de fondo de mucha abertura vertical para la pesca costera

Se ha perfeccionado en los últimos años en Boulogne, un nuevo tipo de arte de arrastre de fondo de mucha abertura vertical del que han sido dotado casi todos los arrastres que componen la flota de pesca costera de la región, o sé como los de otros puertos pesqueros del canal de la Mancha. Derivado del arte semipelágico empleado por primera vez en Francia en 1961, se caracteriza por su sencillez, facilidad de ajuste y robustez. Es claramente diverso del de arrastre para la pesca de la caballa, que es otro tipo de art semipelágico. En cada pernada lleva tres bridas, un calón y una malleta. El funcionamiento de la red y sus accesorios se ha observado con modelos en un estanque de experimentaciones especial. Se emplea en embarcaciones de 13 a 20 m de eslora con motores de 150 a 400 hp; casi todas son arrastreros que pescan por el costado, pero aumenta la proporción de los que lo hacen por popa. El arte de mucha abertura vertical pesca mejor que el tradicional del fondo, particularmente cuando se trata de especies que nadan a cierta distancia de aquel, tales como merluza y bacalao. Su empleo ha puesto de relieve que es imprescindible adapter los artes de arrastre a las condiciones locales y muy provechosa la cooperación entre los pescadores y los tecnólogos especializados en equipo.

LES premiers essais d'un chalut du type semi-pélagique à bord d'un chalutier artisanal d'Etaples en 1961 avaient montré que cet engin pouvait apporter une augmentation sensible de rendement, en particulier pour les poissons nageant à une certaine distance du fond. Malgré ces résultats encourageants, ce type de chalut fut abandonné assez rapidement, du moins sous sa forme d'origine, en raison surtout de sa trop grande fragilité sur les fonds irréguliers et durs de la Manche et du Pas-de-Calais.

L'idée fit son chemin cependant et c'est ainsi que l'on vit apparaître quelques années plus tard un type de chalut de fond à grande ouverture verticale qui était manifestement dérivé du filet semi-pélagique initial, après diverses modifications portant principalement sur la forme du corps du chalut et sur la force des fils.

Cet engin s'est développé rapidement dans la flottille étaploise. Il équipe maintenant, avec des dimensions variables selon la puissance disponible, la plus grande partie des chalutiers artisanaux basés à Boulogne-sur-Mer et Etaples. Par rapport aux chaluts de fond traditionnels, il présente en effet des avantages assez marqués, en particulier des avaries moins fréquentes, une plus grande facilité de mise au point et une amélioration très sensible du rendement et de la composition de la pêche.

Description du filet et de son gréement

Le chalut de fond à grande ouverture est caractérisé principalement par une forme générale ramassée correspondant à un corps relativement bref, à un recouvrement de dos peu important et à des ailes courtes et larges aux têtières coupées en sifflet (fig 1). Les pièces constitutives, de formes simples, sont réalisées avec un nombre restreint de maillages, trois seulement dans l'exemple cité (120, 80, et 70 mm, dimensions maille étirée). Les fils sont en nylon tressé ou câblé; leur force est en général la même pour tout le chalut (600 m/kg en moyenne), à l'exception de la partie terminale de la poche en fils plus forts (300 m/kg environ). Le nombre de sortes d'alèzes à prévoir pour les réparations est donc réduit au minimum; ceci constitue un avantage non négligeable pour le stockage des pièces de rechange ainsi que pour le ramendage.

Par rapport au chalut semi-pélagique du type wing-trawl scandinave (fig 2) on remarque la forme plus courte des ailes et surtout du corps du filet. Cette réduction de la longueur du ventre et du petit dos résulte de l'adoption de coupes plus accentuées, toutes pattes et une maille de côté-quatre pattes (soit AB et 1N 4B, en symboles ISO) au lieu d'une maille de côté-deux pattes (1N2B); elle permet au ventre de se décoller plus rapidement du fond à la suite du bourrelet en évitant ainsi de nombreuses avaries sur les mauvais fonds. D'autre part, le filet est fabriqué avec des alèzes plus résistantes dont les fils sont pratiquement les mêmes que ceux des chaluts de fond classiques.

La comparaison peut également être faite avec un autre type d'engin semi-pélagique: le chalut à maquereau, représenté également sur la figure 2. Ce dernier engin représente lui aussi une adaptation du chalut semi-pélagique, mais pour une autre pêche. Grâce à une forme plus allongée et à l'emploi de fils plus fins, on a pu obtenir un filet filtrant l'eau parfaitement, même aux vitesses élevées réclamées pour la pêche de cette espèce très vivace (4 noeuds au minimum).

La forme allongée du filet à maquereau peut d'autre part être utilisée sans difficultés sur les fonds réguliers de sable fin ou vaseux où ce poisson se rassemble le plus souvent.

Enfin, si l'on rapproche le plan du chalut de fond à grande ouverture de celui du chalut de fond qu'il a supplanté, on constate des dimensions plus importantes, des ailes plus larges coupées en V, ainsi qu'un faible recouvrement relatif du grand dos. D'autre part, les mailles des ailes et du grand dos sont plus grandes que celles du chalut traditionnel; il en résulte une diminution de traînée qui vient compenser l'augmentation de résistance hydrodynamique provenant des plus grandes dimensions du filet.

Le montage du filet traduit également la simplicité générale de conception de l'engin. Les carrés de ventre et de dos sont montés tous les deux à 45 pour-cent (le taux d'armement est exprimé ici selon la recommandation de l'ISO: le pourcentage est égal au rapport longueur de la ralingue/longueur du filet étiré $\times 100$), le bourrelet

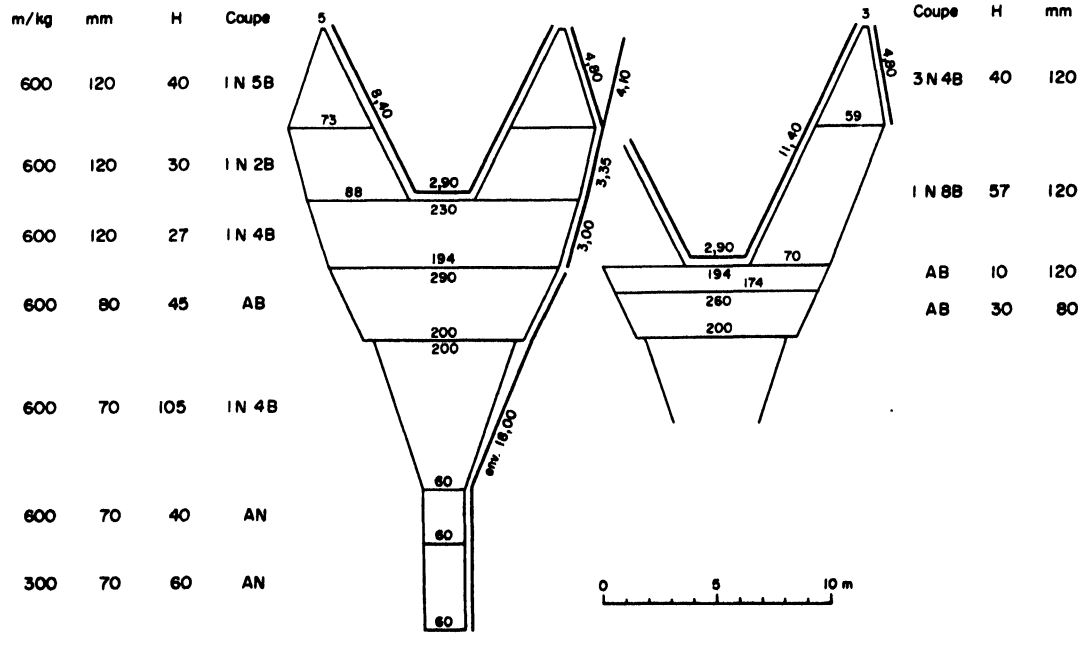

Fig 1. Chalut de fond à grande ouverture 19,70/25,70 pour chalutier de 250–300 ch (plan ISTPM)

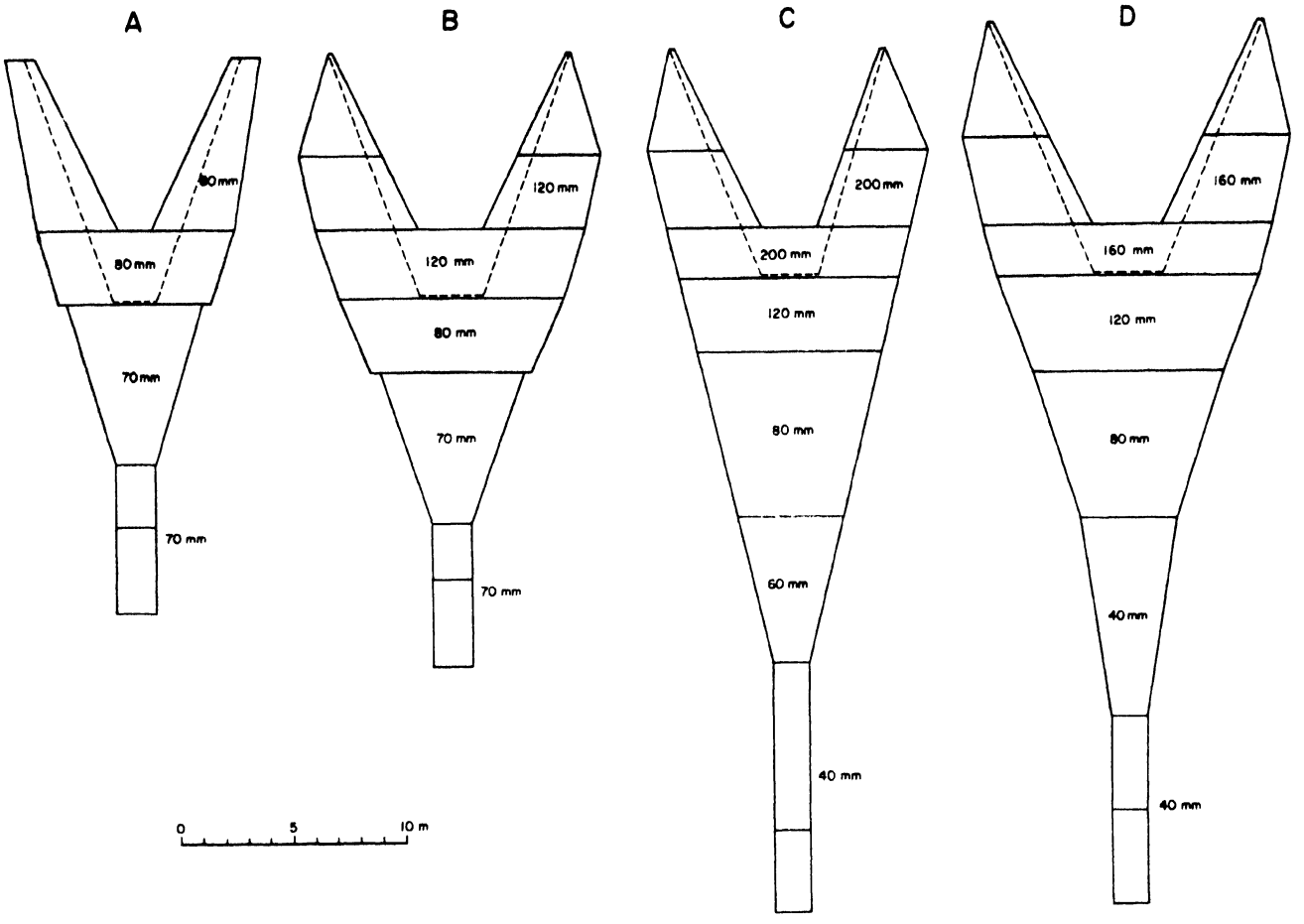

Fig 2. Comparison des chalut de fond traditionnel (A), chalut de fond à grande ouverture (B), chalut semi-pélagique à maquereau (C) et chalut semi-pélagique type wing-trawl scandinave (D)

dans les ailes à 98 pour-cent, la partie antérieure de la ralingue de côté à 93 pour-cent, la corde de dos dans les ailes, la partie postérieure des ralingues de côté et les têtières à 100 pour-cent (le bout libre de la ralingue de côté correspond à 85 pour-cent de la longueur de la pointe d'aile étirée).

Le plan du chalut 19,70/25,70, étudié pour un bateau de 250 à 300 ch, qui est décrit ici ne constitue pas le seul modèle utilisé. En effet, sur la même base, le laboratoire de l'Institut des Pêches de Boulogne a étudié à la demande des professionnels toute une série de plans de filets à grande ouverture pour des forces motrices allant de 50 à 400 ch.

Les modèles les plus utilisés sont jusqu'à présent: le 16,40/21,20 pour 150 à 200 ch, le 17,70/23,10 pour 200 à 250 ch, le 19,70/25,70 pour 250 à 300 ch et le 21,25/28,25 pour 350 à 400 ch.

Il est intéressant de signaler que tous ces plans sont utilisés en général par les pêcheurs sans aucunes modifications, tels qu'ils sortent du bureau d'études de l'ISTPM. Il est vrai que celui-ci dispose à Boulogne d'un bassin d'essais spécialement destiné à la mise au point sur maquettes des chaluts. D'autres part, ses technologistes ont effectué de nombreuses observations à la mer sur des bateaux de recherche ou de pêche commerciale équipés de netsondes, observations qui ont permis notamment de contrôler les constations faites sur les maquettes.

Quelques variantes, portant surtout sur la longueur et le maillage des ailes, ou sur la coupe extérieure des ailes inférieures ont été étudiées cependant en collaboration avec les utilisateurs. Elles ont permis dans certains cas d'améliorer le rabattement en largeur ou d'atténuer une usure exagérée des pointes d'ailes inférieures.

Le gréement

Le gréement participe aussi à la simplicité de l'engin; il comporte essentiellement de chaque côté trois entremises de 10 ou 12 m, un guindineau de 1 m et un bras de 15 m (fig 3). La faible longueur des bras peut surprendre, mais on doit se rappeler que la pêche a lieu en Manche Est par faible profondeur (30 à 50 m en moyenne); des bras plus longs peuvent être employés sur des sondes plus importantes.

Les trois entremises ont la même dimension; en effet, la longueur du bout libre de la ralingue de côté a été calculé selon le pourcentage indiqué plus haut pour compenser la partie débordante des pointes d'ailes L'emploi d'un filin mixte (ϕ 14 mm) est recommandé pour le bout libre et pour la partie antérieure de la ralingue; la partie arrière de celle-ci, montée sur le corps et la poche, étant normalement en cordage de nylon (ϕ 12

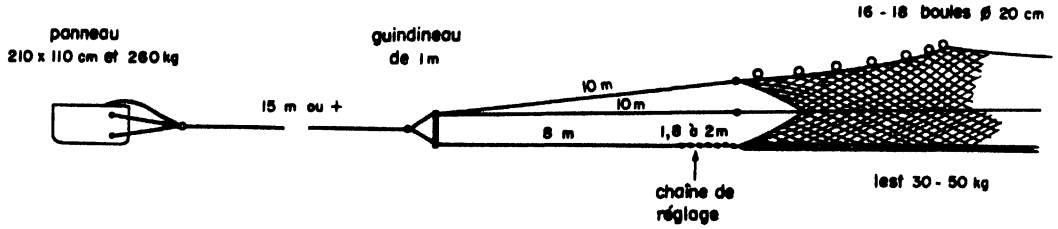

Fig 3. Gréement du chalut de fond à grande ouverture 19,70/25,70

ou 14 mm). Cette disposition avec bout libre préréglé facilite la mise au point; il suffit alors d'agir sur la longueur de l'entremise basse au moyen d'une chaîne de réglage à grandes mailles installée spécialement dans ce but à la liaison entremise—aile inférieure.

En raison du filage assez court des funes, les panneaux sont relativement grands et lourds. Les caractéristiques les plus usuelles sont indiquées sur le tableau 1.

TABLEAU 1. CARACTERISTIQUES DES PANNEAUX DES CHALUTIERS DE PECHE ARTISANALE D'ETAPLES

Dimensions cm	*Poids kg*	*Force motrice ch*
170 × 87	150–180	150
180 × 95	180–200	175
200 × 103	190–210	190
210 × 110	250–280	250
220 × 110	300–330	300
220 × 115	350	340

La corde de dos, en acier fourré, de 9 mm de diamètre, est munie de flotteurs en aluminium ou en plastique d'un diamètre de 20 cm (flottabilité = 3 kgf environ par flotteur), au nombre de 16 à 18 pour un bateau de 250 ch.

Le bourrelet est constitué par un câble en acier de 12 mm de diamètre, garni habituellement de rondelles en caoutchouc d'un diamètre variant de 80 mm dans les ailes à 100–150 mm dans le carré. Il est relié par des chaînettes de longueur variable à la filière en nylon sur laquelle est monté le filet. Cette liaison peut se faire soit directement, soit par l'intermédiare d'un double bourrelet en filin mixte de la même longueur que le bourrelet proprement dit, ce dernier montage étant particulièrement indiqué par fonds durs.

Le lestage du bourrelet est variable; il est en moyenne de 30 à 50 kg de chaînes placées surtout dans le carré et aux coins intérieurs des ailes. Dans la partie antérieure de l'aile du bas, ce lest est complété par la chaîne de réglage dont la longueur (2 m environ) est déduite de celle de l'entremise basse en filin d'acier.

Avec une telle installation, la hauteur d'ouverture est de l'ordre de 3 m, soit plus de 50 pour-cent supérieure à celle du chalut de fond correspondant (1,5 à 2,0 m).

La mise au point de cet ensemble se fait en général sans difficulté. On doit tout au plus équilibrer le lestage ou le boulage, et ajuster la longueur des chaînes de réglage pour faire varier la posée du bourrelet selon les conditions de pêche Ainsi que cela a déjà été indiqué la longueur des bras varie en fonction de la profondeur et du profil du/fond. Enfin, la vitesse de traîne est en moyenne de 3 à 3,5 noeuds. Là aussi, des essais sur maquettes (fig 4) du gréement complet (échelle de réduction: $\frac{1}{10}$ à $\frac{1}{15}$ ème), complétés par des mesures en mer, ont aidé considérablement à la mise au point initiale du gréement en révélant l'influence des différentes parties de cel ui-ci.

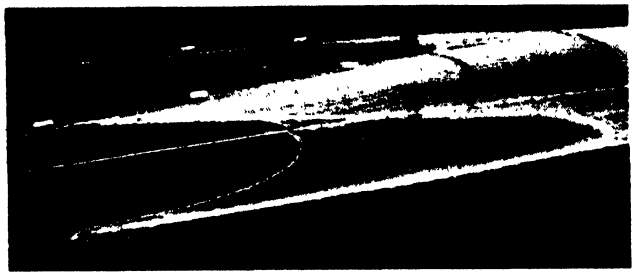

Fig 4. Mise au point en bassin d'essais de la maquette du chalut de fond à grande ouverture

Les navires et leur équipement

La flottille artisanale étaploise groupe une centaine d'unités, en majorité construites en bois, de 14 à 20 m de longueur et de 150 à 400 ch de force motrice. Bien que les équipages soient originaires d'Etaples, presque tous ces bateaux sont basés à Boulogne-sur-Mer où ils trouvent de plus grandes facilités portuaires et surtout un marché plus important pour la vente de leurs prises qui sélèvent à environ 15.000 t par an.

Ce sont pour la plupart des chalutiers latéraux classiques. Toutefois les unités les plus récentes comportent maintenant une installation de pêche par l'arrière avec portique fixe servant à la fois à la manoeuvre des panneaux et à l'embarquement du cul de chalut, avec dans certains cas une disposition avancée de la passerelle (fig 5). Cette disposition plus rationnelle est appelée

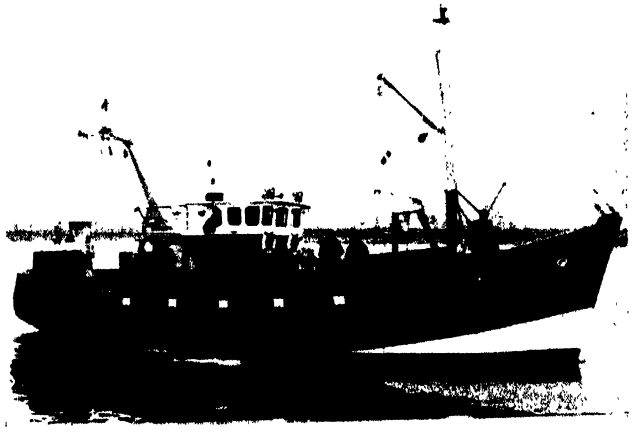

Fig 5. Chalutier artisanal étaplois de type récent avec portique pour la pêche par l'arrière

vraisemblablement à remplacer progressivement l'installation traditionelle de pêche par le côté. Au cours de ces dernières années, on a pu remarquer également un plus grand nombre d'unités construites en acier.

Le treuil de pêche, entraîné par courroie, est parfois commandé de la passerelle. L'hélice est généralement à pas fixe.

Dans la passerelle se trouve habituellement l'équipement suivant; un compte tours moteur, un sondeur enregistreur, un récepteur de navigation Decca et une installation de radiotéléphonie.

L'orientation actuelle des constructions nouvelles semble tendre vers deux types principaux de chalutiers; l'un de 16 m et 300 ch, en bois, et l'autre de 19 à 20 m et 400 ch, en acier. De telles unités paraissent offrir une rentabilité satisfaisante dans les conditions locales d'exploitation: eaux relativement abritées, proximité des lieux de pêche (les marées durent en général deux ou trois jours) et mode de gestion par des patrons-armateurs groupés en coopérative.

Les espèces capturées et la tactique de pêche

La composition des captures effectuées au moyen du chalut de fond à grande ouverture montre une plus grande variété que celle des prises faites au chalut de fond classique; on remarque surtout la plus grande abondance de merlans et morues, ainsi que la présence en quantités appréciables d'espèces pélagiques saisonnières comme les maquereaux, les harengs ou les encornets. Par ailleurs, la pêche en poissons de fond proprement dits, et en particulier en poissons plats, n'est pas modifiée et peut même être augmentée, sous réserves d'utiliser un bourrelet assez fin.

Comme il est d'usage dans les pêcheries de bateaux artisanaux, la prospection des lieux de pêche se fait en flottille, les patrons se communiquant mutuellement, selon les affinités personnelles, leurs observations sur la détection et leurs prises. L'emploi du Decca permet d'effectuer une pêche très précise; comme cela se fait à bord des grands chalutiers de pêche hauturière, les artisans se servent de plans de pêche à grande échelle où sont portés les parcours chalutables, ainsi que les mauvais fonds, les croches et les épaves repérées avec certitude.

Pour faciliter le travail sur les parcours reconnus, en l'absence de traceur de route, certains patrons particulièrement méthodiques préparent à l'avance, à l'intention de l'homme de quart, des relevés d'indications successives de décomètres.

La pêche au chalut de fond à grande ouverture s'effectue de jour comme de nuit, à longueur d'année. Toutefois, certains bateaux se reconvertissent périodiquement aux pêches saisonnières. C'est ainsi qu'on peut signaler l'emploi du chalut-boeuf pélagique au hareng, pendant la saison hivernale, et celui du chalut semi-pélagique à maquereau pendant la période estivale.

Conclusion

Le chalut de fond à grande ouverture, apparu au cours de ces dernières années, équipe maintenant près de 90 pour-cent des chalutiers de pêche artisanale de Boulogne. Ce développement remarquable a attiré l'attention des patrons artisans d'autres ports voisins comme Fécamp, Port-en-Bessin, Cherbourg, Honfleur et Langrune, où ce nouveau filet commence à être adopté en remplacement du chalut de fond classique. On peut dès à présent estimer que cet engin a pris une place prépondérante pour la pêche côtière en Manche, du Pas-de-Calais au Cotentin.

Ce développement spectaculaire d'un filet dérivé "a posteriori" du chalut semi-pélagique appelle deux remarques.

Tout d'abord il confirme le fait qu'il n'existe pas de chalut universel. En effet, les grands chaluts semi-pélagiques en fils fins, analogues aux engins scandinaves utilisés sur les fonds plus réguliers et plus doux de la Mer du Nord et de la Baltique, ne convenaient pas aux fonds irréguliers et durs de la Manche. Il a donc fallu les modifier pour les adapter aux conditions locales sous la forme d'un filet plus court et plus résistant. Simultanément une autre modification aboutissait à la mise au point d'un chalut à maquereau plus long et plus fin.

A ce sujet on peut aussi rappeler la mise au point récente, sur les côtes françaises et espagnoles de la Méditerranée, d'un chalut semi-pélagique spécialement adapté à la pêche dans cette mer; par rapport au plan d'origine nordique, ce filet comporte des ailes plus longues, une forme générale plus allongée et des mailles plus petites qui conviennent mieux à la capture d'espèces de petite taille sur des fonds relativement plus doux.

Ces évolutions bien distinctes démontrent que l'introduction d'un nouveau type d'engin est toujours conditionnée par les particularités de l'exploitation à laquelle il est destiné, notamment par la nature des fonds et le comportement des espèces recherchées.

Enfin, il convient de souligner que l'adaptation et le développement de ces chaluts ont été facilités par les excellentes relations qui existent entre les pêcheurs et les techniciens de l'ISTPM, qui se sont traduites dans le cas présent par une coopération particulièrement fructeuse.

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Le Chalutage Semi-pélagique pour la Pêche du Hareng

A. Maucorps, M. Portier

Semi-pelagic trawling for herring fishing

When fishing for full and spawning herring concentrations on the bottom or close to the bottom, skippers from the northern fishing harbours of France are now using a semi-pelagic trawl with a special rigging called "forks rigging". Moreover, they have on board a complete electronic equipment for detection and trawl control (echo-sounders, sonar and netsonde). With such equipment, they spend most of their fishing time looking for herring schools, cruising at a speed of 12 kn, and shooting the trawl only when a trace is found. Under these conditions catches could be very high for a reduced effective trawling duration.

La pesca semipelagica al arrastre del arenque

Para la pesca de la concentraciones de arenques en fase de prefreza y de arenques jóvenes, que se mantienen en el fondo o cerca de él, los patrones de pesca de los puertos del norte de Francia utilizan una red de arrastre flotante con un aparejo de remolque especial, denominado "aparejo de remolque en horquilla". Llevan, además, a bordo todo el material electrónico necesario para la detección de los peces y el control de la red (sondador acústico, sonar y netsonde). Así equipados, pasan la mayor parte del tiempo a la búsqueda de los bancos de arenques, navegando a una velocidad de 12 nudos, y no largando la red hasta que no han localizado los bancos. En esas condiciones, pueden lograrse capturas muy importantes con un tiempo reducido de arrastre efectivo.

L'UTILISATION du chalut semi-pélagique pour la pêche du hareng s'effectue essentiellement sur du hareng plein et bouvard (stades V et VI de l'échelle de J. Hjort), en Mer du Nord centrale et méridionale, en Manche orientale et en Mer Celtique. Les bancs de harengs sont alors denses, compacts et généralement situés près du fond; s'il arrive qu'ils s'élèvent sur une certaine hauteur, seule la partie inférieure du banc sera exploitable dans ce type de chalutage.

De nombreux pêcheurs ont été intéressés par un modèle de chalut conçu au laboratoire de Boulogne-sur-Mer et dont la mise au point avait été effectuée à bord du navire océanographique *Thalassa* (Nédélec, 1963). En effet, ce type de chalut permet non seulement d'exploiter une tranche d'eau plus importante que celle permise par le chalut de fond traditionnel, mais encore de faire beaucoup moins d'avaries sur les fonds d'accès plus difficiles qu'ils ont été amenés à fréquenter par suite de la raréfaction du hareng dans certaines régions.

Définition

Le chalut semi-pélagique tire son nom du fait qu'il lui est possible de travailler légèrement décollé du fond bien qu'une partie de son gréement, notamment les panneaux, reste en contact avec le sol. Il peut être défini comme étant un chaiut de fond à grande ouverture verticale caractérisé par un faible recouvrement de dos et des têtières coupées en V.

Le plan du chalut semi-pélagique de 35 m (114 ft 10 in) de corde de dos pour 42 m (137 ft) de bourrelet (fig 1), étudié pour des puissances de 800 à 1.200 CV représente sans aucun doute le modèle qui a été le plus utilisé jusqu'alors dans la pêche du hareng bouvard— toutes les indications de gréement données dans le texte se rapportent à ce chalut.

Conception

Les coupes utilisées pour les différentes pièces d'alèze de ce chalut ont été choisies afin de répondre à plusieurs buts.

Le premier objectif à atteindre était l'augmentation dans des proportions sensibles de la hauteur d'ouverture verticale. Ceci a pu être obtenu en donnant une largeur importante aux pièces constitutives des ailes, non seulement à leur base, au niveau du raccordement ailes supérieures-grand dos et ailes inférieures-ventre, mais aussi dans leur partie antérieure.

La diminution du recouvrement de dos favorise l'obtention d'une largeur suffisante pour les ailes inférieures dans la recherche d'une dissymétrie aussi peu marquée que possible. Le maillage généralement adopté dans l'entêture est de 80 mm de côté de maille ($6\frac{1}{5}$ in stretched mesh) au lieu du 70 mm utilisé dans les chaluts de fond, d'autre part le diamètre des fils est sensiblement plus faible.

Ce chalut est toujours employé avec le système dit du "double bourrelet" qui consiste en un bourrelet constitué le plus souvent de rondelles de caoutchouc enfilées sur un filin d'acier soutenu par des chaînettes de 30 à 50 cm (12–20 in) et quelquefois même de 1 m (39 in); chaînettes qui sont fixées sur la ralingue inférieure en mixte du chalut. Le lest, composé essentiellement de chaînes de fort diamètre, est disposé sur ce bourrelet en caoutchouc. Il peut atteindre un poids total de l'ordre de 100 à 150 kg (220-330 lb) pour le chalut 35/42.

Ce dispositif a donc l'avantage de dégager du fond l'alèze de la partie inférieure du chalut tout en permettant au bourrelet de garder un contact intime avec le sol.

Le boulage du filet est réalisé avec des boules en aluminium de 20 cm de diamètre (8 in) dont 40 à 45 sont disposées le long de la corde de dos à raison de 1 boule tous les mètres dans les ailes.

Il faut noter enfin que ce chalut est utilisé pour la pêche du hareng avec un plateau élévateur, moins pour l'accroissement de l'ouverture verticale qui est déjà importante, que pour l'effet de rabattement qu'on lui attribue généralement. Dans ce cas, un plateau élévateur de 75 cm (30 in) sur 100 cm (39 in) est employé avec le gréement à queues et petits bras, ces derniers étant maillés sur les bras supérieurs.

Description

Dans ce type de gréement, inspiré du système Breidfjord, la branche haute de la fourche correspondant au bras issu de l'aile supérieure du chalut est fixée sur la fune, en avant du panneau divergent sur lequel est maillé le bras inférieur (fig 2). Les longueurs de fourches et de bras sont non seulement en rapport avec la grandeur

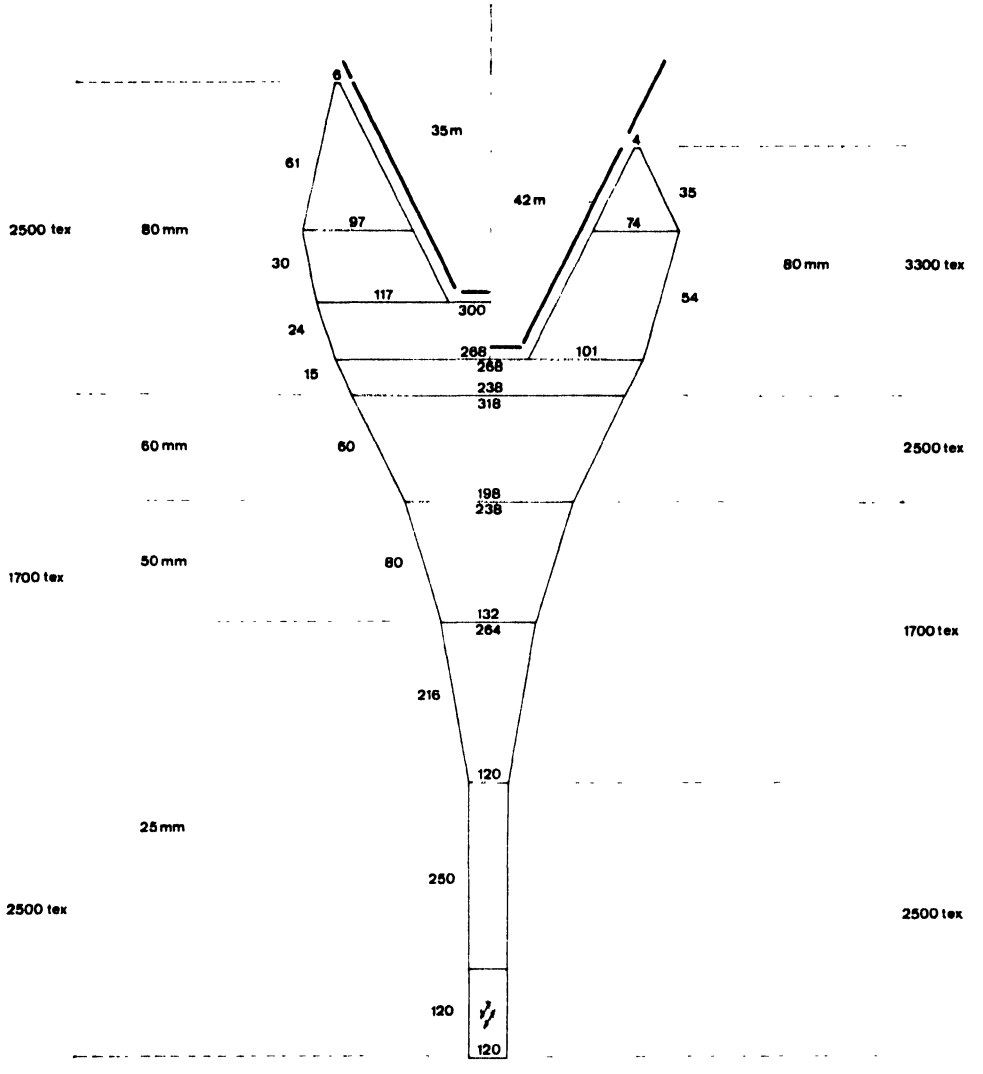

Fig 1. Plan du chalut semi-pélagique 35/42

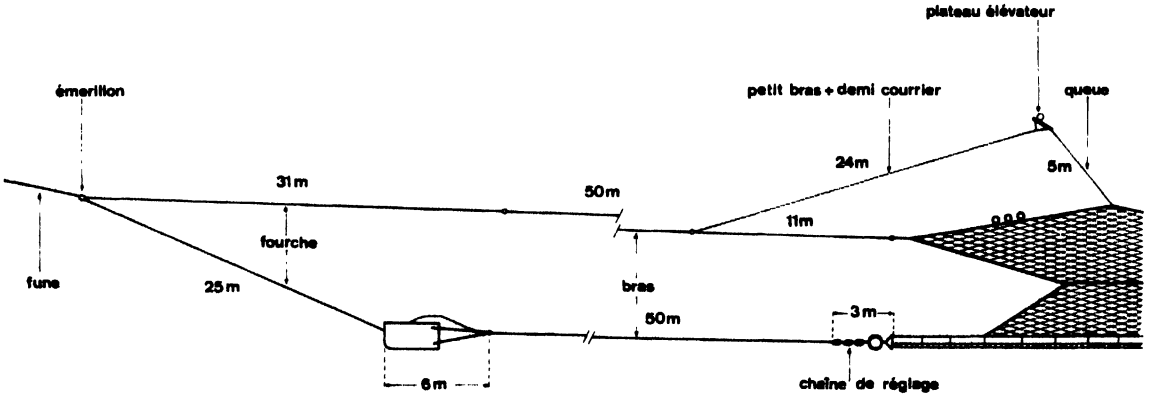

Fig 2. Gréement à fourches du chalut semi-pélagique 35/42 avec plateau élévateur et bourrelet caoutchouc

du chalut mais dépendent également du travail que l'on veut effectuer.

Pour le chalut 35/42, on utilise généralement des fourches de 20 à 30 m (65 ft–98 ft), dimension qui correspond à la longueur de la branche inférieure de la fourche. La position élevée du point de fixation du bras supérieur favorise l'ouverture verticale du chalut qui peut atteindre 8 à 9 m (26 ft–30 ft) avec un boulage légèrement inférieur à celui utilisé avec un autre type de gréement.

La longueur des bras la plus courante est de 50 m (164 ft), mais dans certains fonds particulièrement difficiles où les accidents de terrain (buttes, ridins) se succèdent rapidement il est quelquefois nécessaire de raccourcir les bras, ce qui permet au chalut de suivre mieux les mouvements des panneaux; on emploie alors des bras de 35 m (115 ft).

Les possibilités de réglage sont très grandes et permettent de faire travailler le chalut dans les conditions désirées. Il peut être intéressant, en effet, de gratter le fond ou bien d'en décoller légèrement en fonction de l'allure et de la nature du terrain. Ces réglages sont obtenus en agissant sur différents facteurs:

le hauteur de la fourche; c'est-à-dire qu'en employant une branche inférieure plus longue on facilite l'ouverture du chalut et ses possibilités de décoller;

le filage; s'il est généralement de 2,8 à 3,5 fois la sonde, plus il sera court, plus le point de fixation de la fourche sera relevé et le filet tendra à s'éloigner du fond;

le lestage qui, comme sur tous les chaluts, conditionne la posée du bourrelet sur le fond;

la différence entre les longueurs totales du haut et du bas du gréement qui se décomposent comme suit:

brin de haut: branche supérieure de la fource+ bras supérieur

brin du bas: branche inférieure de la fourche+ panneau+patte d'oie+bras inférieur+chaîne de réglage+sphère et triangle du double bourrelet.

Ce dernier brin est toujours plus long que l'autre et dans le cas d'un gréement homogène, la différence qui en résulte est d'environ 2,50 m à 3,00 (8–10 in), lorsque les panneaux divergents utilisés avec ce chalut semi-pélagique 35/42 sont du type rectangulaire de 1,50 m (59 in) sur 3,00 m (118 in) ou ovale.

La chaîne de réglage a pour but de permettre soit l'ajustement de cette différence si les panneaux sont d'une autre taille, soit la posée plus ou moins grande du bourrelet sur le fond suivant que l'on augmente ou diminue la différence autour d'une position moyenne d'équilibre.

Applications et possibilités

Avec ce type de gréement, l'ouverture verticale d'un chalut semi-pélagique est environ le double de celle du chalut de fond classique correspondant et permet l'exploitation d'une tranche d'eau nettement plus importante.

D'autre part, le chalut semi-pélagique ainsi réglé peut travailler en ne faisant pratiquement pas d'avaries sur des fonds où les chaluts ordinaires risquent de se déchirer très souvent en raison des accidents du terrain ou de la nature de ce dernier (fig 3).

Il s'agit bien, dans ce type de chalutage, de la pêche d'une espèce qui se trouve au voisinage du fond et qui, bien que se développant en hauteur, ne pourrait être exploitée en chalutage pélagique qu'en faisant courir de très grands risques au matériel de pêche (avaries ou perte du filet, détérioration des panneaux hydrodynamiques).

La pêche du hareng, pour atteindre un degré d'efficacité et un rendement économique satisfaisants, nécessite l'emploi conjugué de plusieurs appareils dont la claire analyse par le capitaine du chalutier est un gage de succès.

La recherche en détection

Depuis l'apparition sur le marché des sonars appliqués à la pêche, la majorité du temps est maintenant impartie à la recherche des bancs de harengs qui sont particulièrement bien détectables.

Ainsi que le montrent les photographies d'échogrammes (fig 4), les bancs de harengs généralement denses s'élèvent depuis le fond jusqu'à une hauteur de 10 à 20 m. Ces détections sont parfois si compactes qu'au sondeur la ligne blanche apparaît sur le sommet de la tache dont on peut voir en outre le double écho.

Fig 3. Echogramme de sondeur vertical montrant des détections de harengs bouvards et le profil accidenté du fond dans la région de Bullock (Manche orientale). Les chalutiers équipés de chalut semi-pélagique à fourches ont pu y travailler sans faire trop d'avaries, contrairement aux bateaux utilisant encore le chalut de fond (novembre = Décembre 1964)

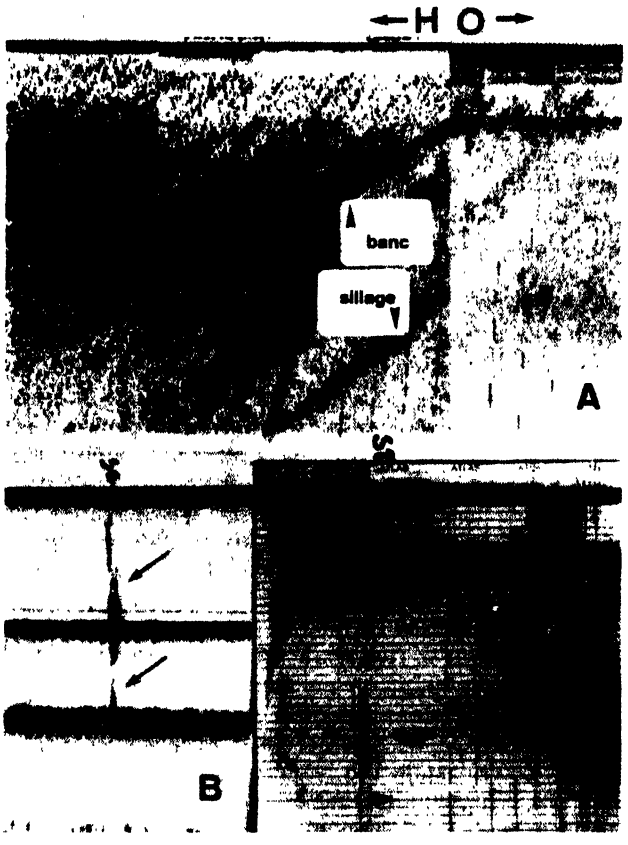

Fig 4. Echogrammes mettant en évidence la technique "de chasse" utilisée pour la capture de bancs de harengs
(a) Détection enregistrée au sonar; noter le passage de la recherche "Horizontale" (H) à celle "oblique" (O)
(b) Enregistrement de la tache sur le sondeur vertical: la ligne blanche apparaît sur le sommet du banc tant celui-ci est dense, noter également le double écho de la détection
(c) Contrôle au netzsonde de l'entrée du poisson dans le chalut

La prospection au sonar se fait à une allure soutenue entre 10 et 12 noeuds; dans un premier temps, la recherche peut être faite en balayage automatique, généralement sur les échelles horizontales de 0–1.500 m ou 0–2.000 m. La faible profondeur d'eau en Mer du Nord limite quelque peu l'emploi de plus longues portées en raison des risques de réverbération du faisceau du sonar sur le fond et ceci malgré la relative homogénéité de la masse d'eau. Par la suite, bien souvent le patron ou son officier-radio effectue une recherche manuelle qui permet de réagir beaucoup plus rapidement lorsqu'une détection est soupçonnée.

Si un banc est repéré de façon précise, la route du navire est ajustée en conséquence et l'opérateur du sonar modifie sa recherche en utilisant notamment des gammes obliques plus courtes.

Dès que le cap est mis sur le banc détecté, le chalut semi-pélagique est filé sauf si cette détection semble trop décollée du fond. La position et l'immersion du banc sont précisées par le sondeur vertical lorsque le bateau passe à l'aplomb du banc; l'entrée du poisson dans le chalut est ensuite confirmée grâce au sondeur de corde de dos (netzsonde).

Cette façon de procéder s'apparente beaucoup à une "tactique de chasse" dans laquelle l'importance des moyens de détection est primordiale.

Manœuvres et rendements

Au vu de l'enregistrement du netzsonde, il peut être jugé nécessaire de virer immédiatement le chalut ou d'effectuer plusieurs passages dans la détection, aussi rapidement que possible, avant que le banc ne se disperse. Dans ce dernier cas les funes sont virées jusqu'au niveau des émerillons qui unissent les deux brins de la fourche. Le bateau peut alors changer de cap rapidement et on

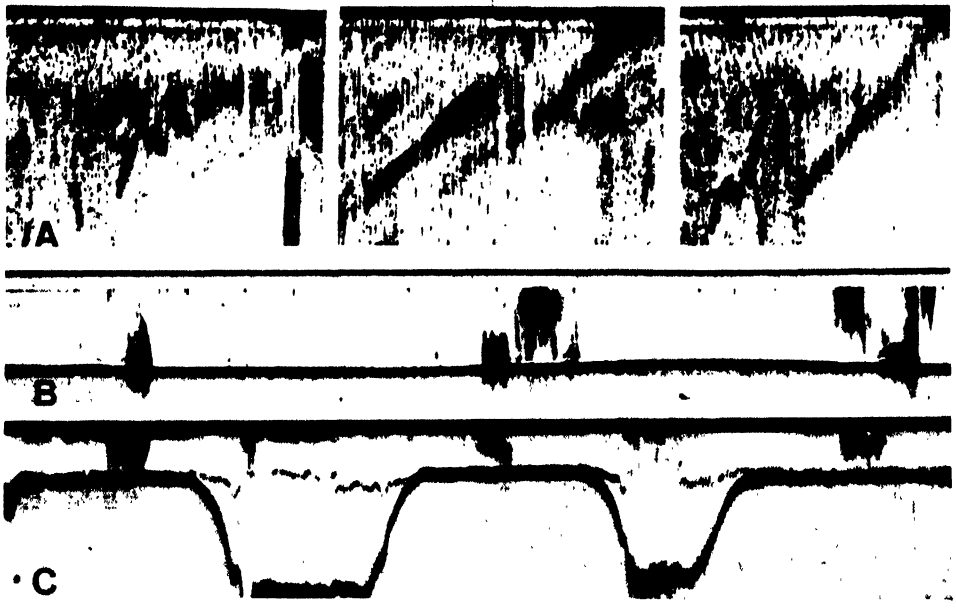

Fig 5. Passages successifs dans le même banc de harengs
(a) recherche au sonar et reprise de la même tache
(b) echogramme du sondeur vertical: le banc se désagrège un peu plus à chaque passage
(c) Enregistrement du netzsonde: après les deux premiers passages le chalut est viré jusqu'aux émerillons de fourche puis rétabli rapidement après le changement de cap; au troisième passage, l'entrée du poisson est plus faible, le chalut est alors viré complètement

refile aussitôt pour rétablir le chalut près du fond (fig 5). Généralement après le troisième passage (au maximum) le chalut est viré et la pêche amenée à bord.

La caractéristique principale de ce chalutage de fond est le temps de traîne du chalut relativement court en rapport avec les tonnages capturés. En effet, les traicts les plus rentables sont ceux qui, effectués sur une détection repérée au sonar, sont exécutés en moins de 30 minutes. Il n'est pas rare alors d'obtenir des captures de plusieurs dizaines de tonnes et bien souvent un trait de 15 minutes environ peut rapporter de 5 à 20 tonnes de harengs.

Conclusions

L'évolution de ce mode de pêche semble se tourner actuellement vers l'emploi de plus grands chaluts. En effet, au cours de la dernière saison harenguière en Manche orientale (21 novembre–23 décembre 1969) certains bateaux ont utilisé le chalut semi-pélagique de 45,50 m de corde de dos (environ 150 ft) au lieu du chalut de 35 m.

Cette technique de chalutage s'est d'ailleurs révélée particulièrement rentable durant cette campagne car elle a permis une rotation très rapide des meilleurs chalutiers qui ont effectué des captures très importantes, de l'ordre de 400 à 600 tonnes par bateau dans les 15 premiers jours de décembre.

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New Dutch Experiences in Two-boat Midwater Trawling with Medium-sized Sterntrawlers

J. F. Minnee

Nouvelles experiences en Hollande de chalutage pelagique a boeufs avec des chalutiers a pêche arriere de moyennes dimensions

Le chalutage pélagique à boeufs a été effectué en Holland pendant plusieurs années par des chalutiers de dimensions limitées, mais depuis 1969 des essais ont été réalisés avec des navires plus gros et de plus grande force motrice pour tenter de compenser la diminution des captures de hareng provoquée par le déclin des stocks et par les limitations de pêche dans certains secteurs. Bien que la mise en pratique de l'engin ne soit pas encore achevée, l'adaptation des chalutiers à pêche arrière pour le chalutage à boeufs a été un succès sans changements importants dans l'équipement. Les essais ont révélé plusieurs faits en rapport avec les tactiques et la taille de navire, ainsi que les particularités techniques et les points de structure qui nécessitent une amélioration. La mise au point d'un navire combiné chalutier/seineur sera vraisemblablement moins profitable en comparaison des résultats obtenus pour les chalutiers polyvalents. Il faut viser dans l'avenir l'introduction de nouvelles techniques qui diminuent l'effort de pêche par unité de capture.

Nuevas experiencias Holandesas de pesca al arrastre entre dos aguas en parejas con arrastreros por popa de tamaño medio y

Durante muchos años, en los Países Bajos se ha pescado al arrastre entre dos aguas en parejas, sirviéndose de arrastreros de moderado tamaño, pero desde 1969 se han realizado experimentos con barcos mayores y de más potencia motris para compensar la disminución de las capturas de arenque a causa de la reducción de las poblaciones y de las restricciones impuestas a la pesca en determinadas zonas. La adaptación de los arrastreros indicados a la pesca en parejas ha tenido éxito, sin necesidad de efectuar cambios importantese ne se tipo, aunque todavía no se han acabado de perfeccionar los artes. La experiencia ha puesto de manifiesto varios factores en relación con la táctica, el tamaño de las embarcaciones, las características técnicas y los puntos estructurales que necesitan ser mejorados. El desarrollo de una combinación arrastrero/cerquero probablemente tendrá menos éxito que los resultados obtenidos con los arrastreros de finalidad multiple. Una posibilidad futura sería la introducción de nuevas técnicas para disminuir el esfuerzo pesquero por unidad de captura.

THE last few years have shown a sharp decline in herring abundance in the North Sea as well as in the Northern Atlantic. This development causes a severe crisis in the fishing industry, processing industry and export economies. In particular, the Netherlands have experienced a loss in production and export of salted herring and affiliated products for human consumption.

The decline of herring production has been partly caused by areas of traditional fishing grounds becoming inaccessible due to national protection limits. Therefore, new ways have to be found to increase herring production. In former years, fishing was good on coastal grounds along the United Kingdom and the Irish Coast but now the only alternative for acceptable fish production is to use pelagic fishing methods.

One-boat pelagic trawling has not been very successful in the Netherlands as the Dutch type trawler has only moderate power and a certain inferiority has been proven in comparison with the two-boat system. This may be due to disturbances in front of the netmouth. The two-

boat system has become popular with the smaller trawlers (up to 28 m long, 500 to 600 hp).

There are a few drawbacks inherent in the two-boat system. These are: (a) Two fully-equipped vessels are occupied during a relatively short seasonal period; (b) The system depends on fairly good weather conditions.

In the framework of Government sponsored experiments, one Dutch fishing company decided to start two-boat trawling using identical medium sized sterntrawlers of a class larger that the usual vessels in size, capacity and horse power.

After a period of overcoming technical and tactical difficulties, these vessels have shown remarkable production.

The gear

Experience in using a 4-panel pelagic trawl indicated the desirability of increased horse power to increase the fishing speed. Even with 50 per cent more power it was found advisable to increase the size of the forward meshes to decrease total net resistance.

The structure of the net needs careful design since the strain, increased by the power, must be carried by fewer meshes. Experience with two 900 hp vessels indicates that the gear needs careful handling during manœuvring.

Initial intentions were to fish without a bow rope to govern the vessels' distance apart, but it soon became obvious that in turning, even with a big radius, extreme caution was necessary to avoid net damage.

Asymmetrical forces on this type of gear can develop very easily and they lead to overstraining of some parts. Tearings appear which cannot be stopped by extra transversal reinforcements. It appeared sometimes as if the net was torn apart by internal pressure though in reality this must have been caused by asymmetrical forces. This problem will be solved by gradually increasing the twine strength where needed. Here information is lacking on the forces and strain on the gear during operations and the need for some device which could supply the required information is emphasized. Some years ago the author proposed a kind of towed submarine, which could be manœuvred in and around the net at a distance, permitting observation even in the turbid waters of the North Sea.

Vessel adaptation and operation

The ideal vessels to be used as pair trawlers have the following characteristics:

1. Open deck aft
2. Multi-drum trawl winch for special service
3. Net drum
4. Protection by fenders
5. Modern electronic equipment.

The open aft deck provides adequate area to handle gear and haul in the catch. Pair trawling with conventional sidetrawler layout, though highly perfected, cannot compete with sterntrawling layout.

The conventional sidetrawler encounters problems with messengerline transfers, particularly when the aft deck is closed. Hauling the catch in on both vessels is difficult since the vessels would have to keep parallel to each other with the catch in between.

Shooting the net consists of transferring the bridle messenger and the bowline to the other vessel, connecting the snaphooks, and paying out the warps. Since bottom and top warps are on different, independent drums, it is possible to adjust the length of each warp to attain the desired shape of netmouth. This has also been found desirable in two-boat trawling with the larger sterntrawlers. Adaptation of the trawlers is kept as simple as possible without changing existing trawl blocks or applying extra blocks.

The bowline, with sufficient strain dampers of nylon rope and automobile tyres, is taken from the starboard auxiliary winch drum and led over the bow with guide sheaves.

Experience and improvements

Experience has pointed out several facts:

1. Electronic fish finding equipment must be of good quality and a netsonde is a necessity for controlling depth of gear.
2. Availability of fish changes very rapidly so that searching must be limited to an area in which both vessels do not separate more than about 5 mi. Searching while the other vessel is occupied hauling does not pay as the time span is too short.
3. When fishing for food-fish, handling and stowing of the catch requires much labour, so that crews sometimes must shift from one vessel to the other. If weather is fair, both vessels take about equal parts of catches.
4. When fishing is good and weather favourable, processing is the limiting factor but these conditions rarely occur.
5. Weather conditions do not usually interfere with fishing by 900 hp sterntrawlers, but seem to interfere with the behaviour of fish or with the accuracy of fish-finding apparatus. Transfer of lines from one boat to the other does at times produce severe problems even with the application of heavy rubber tyre fenders. Several proposals have been made which may enable transfer of lines without closing in to a hazardous proximity, e.g. use of buoys, power shooting etc. Experience has shown that damage to vessels occurs more often in fair weather when the captains dare to take risks. When the sea is choppy they are more cautious. In this respect it is felt that bigger vessels will probably be even more vulnerable to damage because of their weight. Vessel size is thus limited and productivity is curtailed until better transfer techniques can be found. When building new boats, certain regions at the bow and aft quarter may have to be reinforced and shaped differently to reduce damage. Fenders of inflatable type may also help, but placement along the sides must be correct.
6. The bowline system must be improved to protect this line from damage due to shock and chafing. Adjustments to length of line have proved adequate, so that no separate bowline winch needs to be considered although this would enable better control of vessels when manœuvring.
7. Independent top and bottom warp control proved of utmost importance for controlling gear depth and productivity. The 4-drum winch, controlled from the bridge, seems basically indispensable for efficient pair trawling.

8. Human factors are involved as good cooperation is required between captains and crews.

Future developments of combination arrangements

With adaptation of standard sterntrawlers for pair trawling without changing basic fishing equipment, it is obvious that combination trawling is possible. The net drum has found acceptance also for bottom trawl gear (without bobbins). Changing from one gear to the other during a trip has not yet been tried on Dutch trawlers.

Whether the principle of combination systems has practical advantages, compensating for the additional capital investment in different types of gear and spares, has not been proven. Efforts will be made to find a gear that can be used for both bottom and midwater trawling. In this the combination vessels have a layout of equipment that is basically sound for optimal conventional trawling, while gear is being developed to allow multipurpose use.

Combination arrangements that could also include purse seining were described in the paper presented at the Third FAO Fishing Boat Congress, Gothenburg, (1965 Minnee, J. F., New Trends in Stern Fishing, *Fishing Boats of the World 3*, Fishing News (Books) Ltd., London, 1967, pp. 572–582). The application of this system is mainly restricted to industrial fishing for fish meal since the catches are very irregular and not in accordance with the vessel's capacity for processing. Since herring abundance seems to have declined to a critical stage, the fish should be reserved for direct human consumption rather than processed into fish meal. With current methods, food-fish is still being produced at costs that are comparable to agricultural food products. For this reason the development of better fishing methods and equipment should continue in an attempt to produce fish with less effort per unit of catch.

Deck Layout and Auxiliaries for Handling Midwater Trawls

W. Karger

Dispositif et auxiliaires de pont pour la manœuvre des chaluts flottants

Dans le cas des gros chalutiers pêchant par l'arrière, il faut réduire les besoins de main-d'oeuvre et améliorer les techniques de manœuvre des filets. Etant donné l'accroissement constant des dimensions et de la force motrice des bateaux, le volume des chaluts flottants dépasse actuellement 13 m^3 et leur longueur peut atteindre 200 m. On a avancé de nombreuses propositions pour mécaniser de diverses façons la manœuvre des filets. Certains de ces systèmes sont utilisés sur les gros chalutiers pêchant par l'arrière et d'autres sur de plus petits bateaux. Parmi les cinq méthodes différentes de manœuvre des filets examinées, le filet à tambour semble offrir les plus vastes perspectives d'application.

Distribución el la cubierta y maquinaria auxiliar para la manipulación de las redes pelagicas de arrastre

En los grandes arrastreros por popa es necesario reducir la mano de obra simplificando las técnicas de manipulación de la red. Al aumentar el arqueo de la embarcaciones y la potencia de sus motores, las redes para el arrastre a profundidades intermedias han ido aumentando de tamaño, hasta superar 13 m^3 de volumen y 200 m de longitud. Se han hecho muchas propuestas para mecanizar la manipulación de la red. Algunos de esos sistemas se emplean en los grandes arrastreros por popa, y otros en las embarcaciones más pequeñas. De los cinco métodos de manipulación de redes presentados el carretel para red parece ser el que más posibilidades de empleo ofrece.

ONE-BOAT "aimed" midwater trawling with netsonde is a comparatively new fishing method. This is especially true for long distance sterntrawlers which started this on a real commercial scale only three to four years ago.

In the beginning the size of midwater trawls increased slowly, but after it was found bigger mesh sizes in the opening for reduced towing resistance did not affect catching efficiency, sizes considerably increased.

Most new German sterntrawlers were fitted out with filleting plants and deep freezing equipment. Fish hold capacity was gradually increased to 1,000 and even 1,800 m^3 (35,300 to 63,500 ft^3). Both measures enable vessels to stay longer at sea. The increase in length overall to 85 and 100 m (280 to 305 ft) provided more space between winch and ramp thus facilitating hauling.

All these developments required more powerful engines. The average installed engine power for propulsion increased from 1,950 hp in 1960/61 to 2,800 hp in 1968/69 in the German Federal Republic (fig 1). It can be expected that 4,000 hp for propulsion—some 40 tons thrust for trawling—will be available in the near future.

Parallel to the propulsion, trawl winches become more powerful. In addition to hauling the gear, the winch is needed during midwater trawling to vary the depth of the net to cope with the fish schools observed by ship's echo sounder and/or netsonde. Consequently, the pull of the winch has to be approximately equivalent to the thrust of the propeller (fig 1). So it is expected that, in relation to about 4,000 hp for propulsion, the winch power will reach 600 to 800 hp.

Until now, chiefly small trawlers have realized some of the ides of mechanized gear handling to reduce manpower and operation time. The reason may be that the

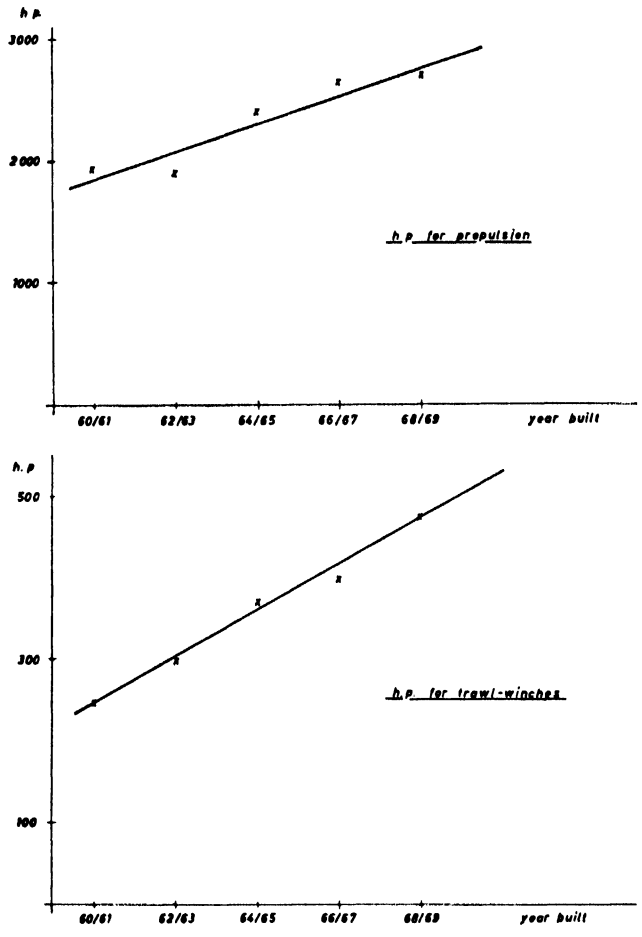

Fig 1. Development of power for propulsion and trawl winches of the sterntrawlers of the German Federal Republic

deck space increased with the length of the vessels to more than 30 m (100 ft), allowing the haul in five steps of a midwater trawl with a length of 150 m (490 ft).

In the last few years the big midwater trawls have reached a volume of some 13 m^3 (460 ft^3). If such a net lies in loops on the deck behind the winch, no other trawl can be shot before the first one is stowed away. The following are some proposals to solve this.

Dividing the deck into two areas

It has been proposed to divide the deck of a vessel symmetrically in such a way that two trawls can be handled alternatively. The katamaran *Experiment* of the U.S.S.R. has two ramps and decks, one on each hull. To handle two trawls alternately may also be possible on board big one-hull trawlers. In this case the ramp itself and the dumping hatch could be used for both trawls and the deck would be divided into two parts like a "V". For repairing and changing the gear this proposal has some advantages. A time calculation made in the German Democratic Republic shows that remarkable time savings can be expected (Strobel, 1966).

Some sterntrawlers have special net platforms above the stern ramp. This position is, however, inconvenient for handling. A better solution may be to have the net platform not above the stern ramp but behind and above the net winch. The main advantage of this position is that the trawls can be stowed in such a manner that they can be shot directly from the platform into the water. Of course this is only possible for trawls without heavy bobbins.

Split net system

The so-called split net system is particularly prevalent in the Netherlands but is only used for sterntrawlers without a ramp. After the wings are taken on board the net is pulled with a messenger over a net block mounted at the bipod mast till the codend can be taken with the bull rope (fig 2). Using this method it is not necessary

Fig 2. German 50 m vessel Milly Ekkenga *equipped for the so-called split net system*

to take the whole net aboard (Minnee, 1965). On the other hand bigger catches cannot be taken in one go but have to be split, which is time consuming. Normally this arrangement is combined with a small free deck area at the stern. Therefore, in bad weather net handling is not without difficulties.

Powered block

It was a lucky coincidence when some purse seiners equipped with a powered block changed over to trawling. It was then discovered that the powered block is also very well suited to hauling trawlnets. When the wings come on board they are put in the block and the whole net can be hauled by one man only. This method is easy, not expensive and needs little deck space. It would be less suitable for large trawlers as it is too dangerous

to handle the net while such a vessel is rolling and pitching in heavy seas.

Net drums

The most important auxiliary device to handle trawls is the net drum. Probably originally developed in North America for seine nets, the drum was used later on for bottom trawls. In 1967, the British White Fish Authority tested a hydraulically driven net drum for bottom trawls on side and small sterntrawlers. The result was that two men are enough to handle the net with a net drum in a shorter time than four men without drum. Chaplin (1968; N.N. 1968) proposed the following dimensions for a net drum for the trawler *Ross Daring* L_{oA} = 108 ft (33 m):

Flange diameter	54 in (1.37 m)
Core diameter	12 in (0.31 m)
Distance between the flanges	72 in (1.83 m)
Horsepower at winch	35 hp

Before that a 30 m sterntrawler without ramp, built in the German Federal Republic in 1965 specifically for midwater trawling, was equipped with a low pressure hydraulic driven net drum. The capacity of the net drum was calculated for trawls up to 2,000 meshes circumference (200 mm mesh size stretched). After some initial difficulties—the bridles ran one upon the other; the floats were forced through the wing meshes—the crew was very satisfied (fig 3).

Fig 3. German 30 m cutter Schleswig-Holstein*; the pennants and bridles are wound on the net drum*

Later Swedish fishermen recognized the advantage and many net drums were installed for handling two-boat midwater trawl nets. The drum—normally driven by a high pressure hydraulic motor—is usually mounted just in front of the wheelhouse at starboard side (figs 4 and 5). The advantages of the net drum are particularly evident in bad weather. They also improve safety.

On modern sterntrawlers the pull of a filled net drum should be of the same order as the pull of the analogous winch. Modern net hauling winches have a pull of about 5 tonf at a hauling speed of 20 m/min and of 2.5 tonf at 40 m/min. The main dimensions of net drums are given by the distance between the flanges and the flange

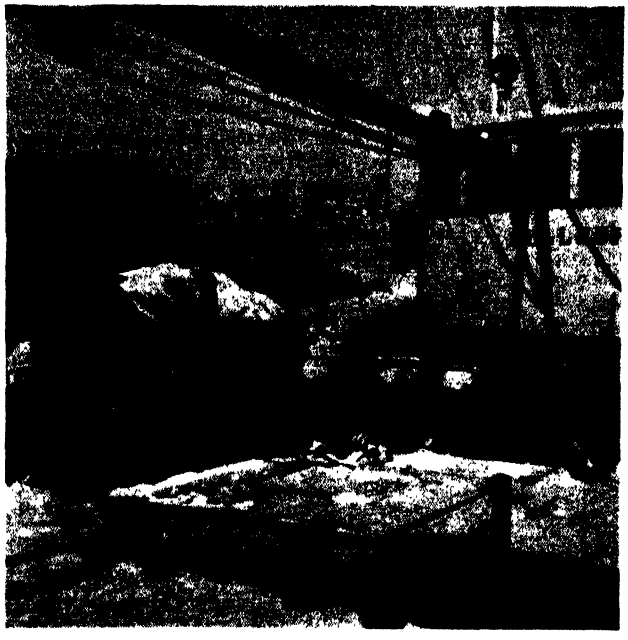

Fig 4. A net drum installed on a Swedish cutter

Fig 5. Non-powered net drum mounted at the stern on a Dutch cutter

diameter. In fig 6 the dimensions are given without the bearings and the electric or hydraulic motor. The relation between engine power, flange diameter, constant hauling speed of 20 m/min (65 ft/min) and maximum pull of the full drum at an efficiency of 0.85 is as shown in Table 1.

TABLE 1.

Flange diameter	*Maximal stall torque*	*Speed*	*Horse power at winch*
m	*tonf m*	*m/min*	
1.6	8	20	34
2.0	10	20	53
2.4	12	20	75
2.8	14	20	103
3.2	16	20	134

TABLE 2.

Number of meshes circumference. Mesh size, stretched = 56 cm	*Number of floats (20 cm diam) normally used*	*Weight of net without bridles and frontweights*	*Volume of net without bridles and frontweights in loose and dry condition*	*Length of net stretched without codend*	*Length of net stretched including the codend (codend = 19 m)*
		t	m^3	*m*	*m*
572	80	1.1	5.6	94	113
715	100	1.45	7.0	115	134
788	100	1.6	7.7	132	151
948	150	2.1	10.2	159	178
1114	150	2.3	11.5	178	197
1250	150	2.7	12.8		

Note: The volume of a trawl is less when wound up wet and under stress.

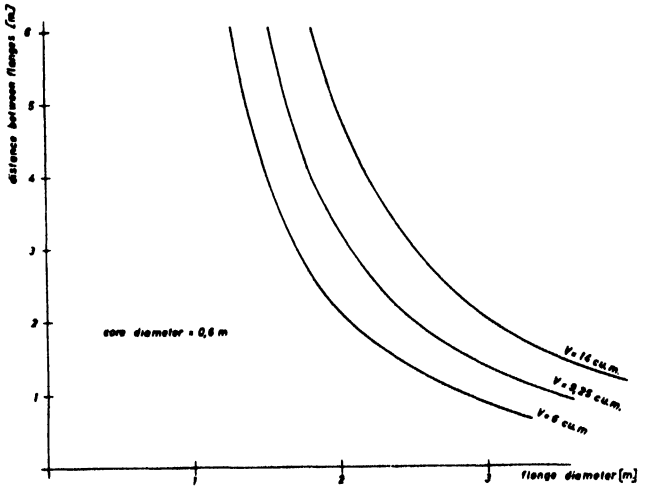

Fig 6. Main dimensions and resultant capacity of net drums

The above table gives some guidance for calculating the distance between the drumflanges, and the volume and the weight of different midwater trawls.

The experiences encountered in the cutter fishery of several countries show that trawl handling could be simplified on board with the introduction of the net drum. On Swedish cutters the crew could be reduced by two men (N.N., 1961; Reid, 1965; N.N., 1965; High, 1968).

Observations on board sterntrawlers with ramp confirm that the pull of the hoisting tackle must correspond to half the weight of the catch to haul it on board. As midwater trawl catches may reach up to 100 ton, the hoisting tackle must have a pull of about 50 ton. Therefore, normally two hoisting tackles are used, driven directly by the trawl winch.

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Improved Handling of Trawl Gear

G. A. Traubenberg

Améliorations de la manœuvre des chaluts

Un système de chalutage comportant un double engin de pêche et des treuils à simple action est proposé; à bord de grands chalutiers à rampe arrière du type *Mayakovsky* et *Pushkin* il permet de réduire la durée du filage et du virage (non comprise celle du filage et du virage des funes) d'environ 50 pour-cent et le nombre de matelots de pont de six à quatre hommes. Ceci est obtenu en remplacant le treuil de chalutage polyvalent traditionnel par des treuils séparés pour les funes et par un certain nombre de treuils à simple action qui sont tous manœuvrés d'un poste central de contrôle. On se sert alternativement de deux trains de pêche complets de telle manière que le deuxième engin peut être filé avant que l'on ait vidé la capture du premier engin viré juste auparavant.

Pesca al arrastre racionalizada

Se propone un sistema de pesca al arrastre con dos artes y con maquinillas especialmente diseñadas, gracias al cual es possible, en los grandes arrastreros con rampa a popa (por ejemplo del tipo *Mayakovsky* y *Pushkin*) reducir en un 50 por ciento el tiempo necesario para largar e izar (excluido los cables), y la tripulación de cubierta de seis a cuatro hombres. Esto se consigue substituyendo la maquinilla tradicional plurivalente con maquinillas de varios carreteles y con varias maquinillas especialmente diseñadas accionadas desde un punto central de control. Se pesca con dos redes completas que se emplean alternativamente, de forma que es posible largar la segunda apenas halada la primera, antes de que se haya vaciado la captura.

EXPERIENCE accumulated shows that sterntrawlers are superior to sidetrawlers but also that there is still hope for further improvements.

In the USSR perfection of the sterntrawling technique is being developed along three closely interrelated trends:

(a) Reduction in number of shooting-hauling operations and streamlining of trawling cycle
(b) Development of new equipment for handling fishing gear, resulting in a further increase in hauling power and speed
(c) Reduction in number of deck crew by greater efficiency in trawling cycle operation.

"Trawling cycle"

The term "trawling cycle" covers a complete tow, i.e. shooting the trawl, paying out warps, actual towing, hauling of warps, hauling in of the trawl, discharge of the catch and preparation of the trawl for the next tow.

The trawling cycle time may be subdivided into four groups:

(a) Variable time expenditure dependent on trawling depth (paying out and hauling of warps)
(b) Variable time expenditure dependent on size of the catch
(c) Constant time expenditure necessary for normal shooting and hauling of trawl gear
(d) Time utilized for towing.

The efficiency of a day's catch is determined by the number of cycles under conditions of optimal duration of towing adopted for a given fishing ground.

The number of trawling cycles per day "N" is determined by the following equation:

$$N = \frac{24 \times 60}{T^{I} + T^{II} + L\frac{V_1 + V_2}{V_1 \cdot V_2} + T_1 + T_2}$$

where T^{I} = time consumed for the trawl shooting (min)
T^{II} = time consumed for the trawl's retrieval (min)
L = warp length employed (m)
V_1 = rate of shooting warps (m/min)
V_2 = rate of hauling warps (m/min)
T_1 = duration of towing (min)
T_2 = time for discharging catch (min)

Catching efficiency depends naturally on time spent in actual towing. Time consumed on all other phases of the trawling cycle is unproductive auxiliary time. By reducing this auxiliary time for each separate cycle overall efficiency of trawling can be improved.

The trawler's deck layout consists of a system of auxiliary devices and arrangements for shooting and hauling the trawl, for handling otter boards and for disposing of the catch.

Number and type of devices and their arrangement on deck determine the number of single operations and time required for each as well as the number of crewmen needed.

Guy rope system

The guy rope system which is generally used by the *Mayakovsky* and *Pushkin* type trawlers requires six men. Two of them operate the trawl winch, which is a complex aggregate and requires frequent manual operation of four brakes, four coupling gears and control of drum rotation rates during shooting and hauling. Two men are required on each side for handling the otter boards, bridles and guy ropes, particularly during hauling. This deck team of six men (four fishermen and two winch operators) spend about 10 min on shooting and about 17 min on hauling the trawl, including the discharge of an average 2.5 to catch, excluding the time needed for shooting and hauling the warps.

Improved winch design and arrangement

To simplify the operation pattern it is proposed to replace the conventional multi-purpose trawl winch with a series of single purpose winches, including separate single drum warp winches. All these winches should be remote controlled by one man from a central panel.

This system of several single purpose winches would provide the following advantages:

(a) Separate warp winches avoid loss of time, e.g. for equalizing the warp length when hauling otter boards to the gallows.
(b) Separate warp winches and bridle winches put an end to heavy and dangerous labour. Otter boards remain attached to warps which reduces handling time for shooting and hauling with regard to otter boards and also warps.

(c) Due to proximity of separate warp winches to the stern, they would be in line with the towing blocks. This would extend cable service life.
(d) Freeing the working deck from warps and other cables permits processing fish on deck while the trawl is being operated and improves safety conditions.
(e) Remote control from a central panel requires only one winch operator.

The analysis of the separate winch system shows a reduction in the number of operations from 23 to 16 by eliminating the following operations:

1. During shooting: engagement of guy hooks
   engagement of board rope spans
   removal of board chains.
2. In hauling the trawl: the receipt of boards
   disengagement of board rope spans
   fastening of guys
   release of connecting ends from rollers.

The exclusion of these operations permits a reduction in trawl shooting time from 10 to 7.5 min and hauling time from 17 to 12 min. The total economy of time per cycle amounts to 7.5 min savings. If the remote winch control is situated close to or in the wheelhouse the functions of the winch operator may been trusted to the navigation crew (the deck navigator or the helmsman) so that only four men, including the fish master, are needed for the performance of all operations of the trawling cycle on deck.

"Doublet" system

The "Doublet" system provides for the intermittent operation of two trawls. For this purpose it is desirable to install two separate sets of bridle winches arranged in such a way on the working deck to enable lifting of the first trawl along the ramp while the second trawl is ready for shooting. Hence, the time required for preparation of the trawl is eliminated from the shooting-hauling cycle. The same applies for the time needed for the discharge of the catch which together with preparation and repair of the trawl just hauled is done after the other trawl has been shot and is being towed. In this way the total time for shooting and hauling of the trawl (excluding the hauling and shooting of the warps) amounts to 14.5 min or about 53 per cent of the traditional system. All the operations are conducted by four fishermen and one winch operator (navigator or helmsman). The total number of operations is 15.

Results of some Basic Calculations of Vessel and Gear Tracks and on Fish Interceptions, in Aimed Trawling

P. R. Crewe, P. D. Chaplin

Resultats de quelques calculs fondamentaux sur les parcours du navire et de l'engin et sur les interceptions de poisson dans le chalutage controle

Il a été démontré que le parcours des chaluts de fond et pélagiques en rapport avec le déplacement d'un chalutier donné peut être obtenu par des méthodes analytiques appropriées à la programmation d'un ordinateur. Ceci comprend des parcours de navire relativement compliqués, comme des spirales s'achevant en cercle, des passages en avance et en transition à descerc les terminaux du type effectué par les navires en route libre, et des mouvements oscillatoires tels que ceux obtenus dans les essais de manœuvre de *Kempf*. Des portions de différents types de parcours peuvent être combinées. On effectue aussi des recherches sur la "modernisation des procédures d'interception" qui réclame un contrôle continu de la position de la cible par rapport au chalutier. Les techniques d'interception et de pour-suite d'un parcours sur le fond peuvent être rendues plus précises à l'aide d'une instrumentation déterminant la position relative du chalut par rapport au chalutier. On doit prêter attention au fait que la réussite de l'interception est limitée par l'affaissement de l'engin et par les possibilités de manœuvre du bateau.

Resultados de algunos calculos basicos sobre rutas de barcos y caminos seguidos por los artes de pesca, y sobre interceptaciones de bancos de peces en la pesca al arrastre dirigida

Se ha comprobado que puedo establecerse el camino seguido por las redes de arrastre flotantes y de fondo, correspondiente al rumbo de un arrastrero dado, mediante métodos analíticos susceptibles de programarse en una ordenadora. Esto comprende rutas de barcos relativamente complicadas, desde espirales hasta círculos terminales, desde cambios de avance y de rumbo hasta círculos terminales del tipo que producen los barcos al navegar libremente, y movimientos oscilatorios tales como los obtenidos en las pruebas de maniobras *Kempf*. Se pueden combinar segmentos de las distintas clases de caminos seguidos. También se están investigando "procedimientos de actualización de la interceptación" que exigen una vigilancia continua de la posición del blanco respecto al arrastero. Las tecnicas para comprobar la interceptación y las rutas seguidas respecto al fondo marino se pueden hacer mucho más precisas mediante el empleo de instrumentos que establezcan la posición relativa de arte con respecto al arrastrero. Se debe prestar atención a las limitaciones que en el éxito de la interceptación ejercen el hundimiento del arte y la maniobra del barco.

OVER the past years there has been increasing interest in equipping fishing vessels with computers. Initially, plans have been confined to research vessels and the first system has recently been installed in the *F.R.S. Explorer* operated by the Marine Laboratory, Aberdeen.

Within the next few years additional installations on a Norwegian research vessel, on a research vessel being

built in Poland under the joint auspices of F.A.O. and the Polish Government and on a distant water British freezer trawler, will also come into service.

Although these computer facilities are primarily intended for research purposes, they may also be used to solve some tactical problems in fishing which have previously been too complicated for a real time solution to be obtained by other methods. One such problem arises where fish are detected at some range and bearing to the vessel and action is required to ensure that the trawl passes through this target. The need for a solution to this problem is becoming more urgent now that scanning sonar is being developed and may be introduced into the fishing fleets on a wide scale in future. This type of equipment is currently limited to a range of about 100 fm for bottom fishing, but it is anticipated that this will be greatly increased in future developments. The need is therefore for a theory which is not confined to bottom fishing, nor by the current capabilities of equipment, but treats the problem in a general manner.

In using such a theory, procedure would be to compute a course of action on the part of the vessel to bring the trawl to the expected position of the target at some future time. After a sub interval of this time such as 30 sec or 1 min the computation would be repeated and a revised course of action obtained. Further updating would then take place on a regular basis until the target had either been captured or had escaped, or a better target had presented itself.

A complete theory is likely to be complex and will involve a large and fast computer to give solutions in the short time scales necessary. It will require a comprehensive system of measurement as indicated in Table 1 and therefore could only be considered for research vessels. For commercial fishing a more simplified instrumentation and analytical procedure would be essential.

TABLE 1. VESSEL AND TRAWL GEAR PARAMETERS NEEDED FOR A COMPREHENSIVE UPDATING INTERCEPTION TECHNIQUE

Ship's speed through the water by two component log
Ship's speed over ground by Doppler log or equivalent
Relative wind speed and direction
Warp tensions
Vertical and horizontal angles of warps relative to vessel centre line
Vessel thrust
Vessel heading
Rudder angle
Rudder stock torque
Warp tensions just ahead of otter boards
Otter board angles of heel
Gear speed over ground
Headline height

A complete theory is currently being developed by the British Hovercraft Corporation under contract to the White Fish Authority (British Hovercraft Corp. 1970). This paper reviews the current state of that work in non-mathematical terms.

An important refinement has been consideration of the effect of manœuvring on the curvature of the warps, particularly in the horizontal plane. This can cause the bearing of the trawl from the ship to differ significantly from the direction indicated by the warp angles at the ship. Further, it affects the simple assumption on which previous geometrical construction of trawl tracks has been based. The expression of the curvature problem is rather different in manœuvring and in holding a given gear track over the ground, in the presence of cross tide and wind.

A number of problems are still in the course of investigation but only those for which a solution has become apparent are now discussed. In particular, full-scale manœuvring trials data, in towing conditions, are required to determine the vessel track immediately following a step change in helm angle. In this paper it is assumed that a circle of required radius can be entered without transition, but results of mathematical procedures for dealing with practical transitions are considered also, in readiness for utilizing trials data when it becomes available.

Although the general vessel and gear track behaviour described applies equally to bottom and to midwater trawling, there is a qualitative difference in the warp load with speed variations, that has some effect on the relative directions of vessel and gear motions during a manœuvre. The detailed warp shape theory (Crewe 1960; British Hovercraft Corp., 1970) covers these differences. Furthermore, however, gear asymmetry during turning will involve differences in depth below the sea surface, between the starboard and port otter boards. This latter behaviour depends not only upon warp shape in elevation, as well as planform, but also upon the balances of forces and moments that act upon the otter boards.

The British Hovercraft Corporation is currently developing procedures for computing the otter board equilibrium orientations that depend upon the latter.

PREVIOUS WORK

Karapuzov (1966) and Crewe (1966) reported independently studies into the track taken by a trawl when the towing vessel carried out manœuvres. They both suggested that the position of the trawl relative to the vessel could be obtained by simple geometrical constructions, as exemplified in cases 2 and 3 of fig 1. The figures used in this paper have been reproduced from British Hovercraft Corp. (1970) and therefore contain some mathematical detail that can be ignored in the present context.

Subsequently Dickson (1968 and 1969) presented two notes to the International Working Group for Fishing Technology in which he considered the problem of intercepting a moving target. Dickson has pointed out the need to establish the relative speed and direction of the target to the vessel. This necessitates a short period of observation of the target and a consequent reduction in the time available for manœuvring to achieve interception.

The analytical work of British Hovercraft Corp. (1970) that has produced the results given in the present paper, defines vessel and trawl motions by means of the "intrinsic" variation of track angle to an arbitrary datum direction, in terms of distance along the track. This has proved to be a simple and powerful method for deriving the basic equations, and is economical for computing.

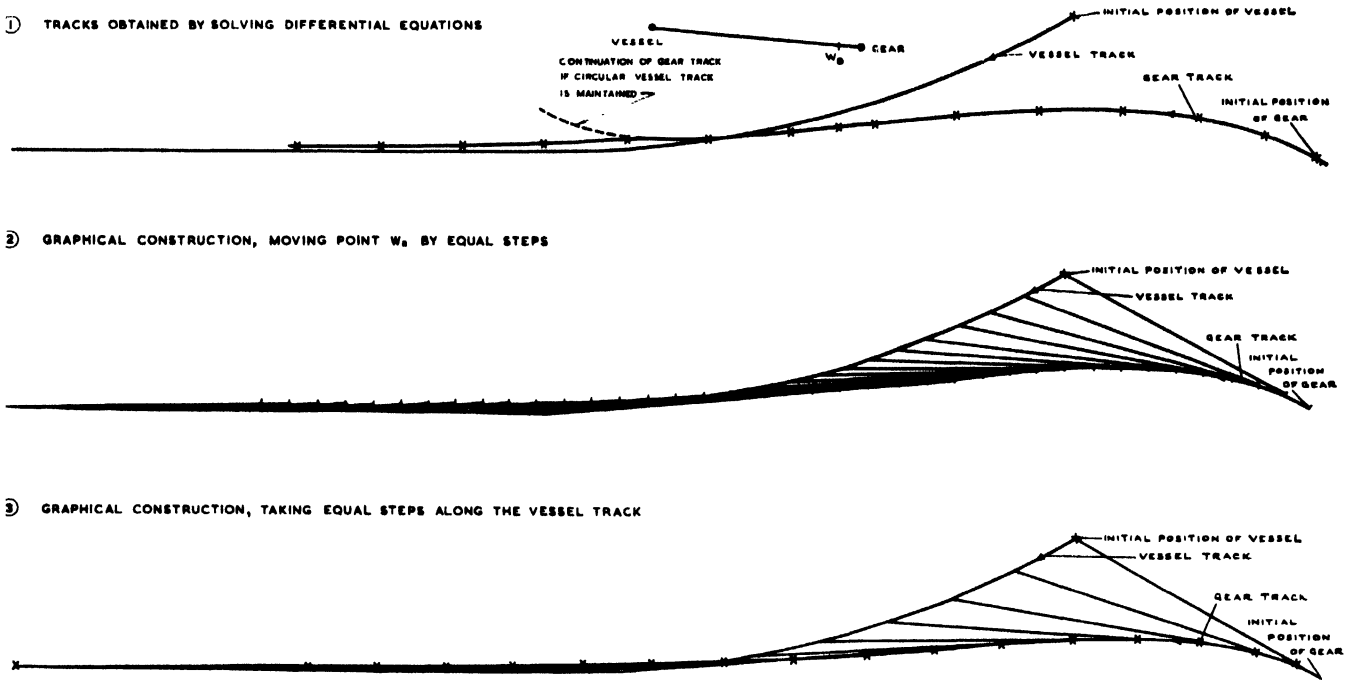

Fig 1. Comparison of computed and constructed tracks, taking the point W_s as moving directly towards the position of the vessel at each instant where W_s is at 90% of the distance from the vessel to the gear

Also, in discussion of the vessel motion, it is often unnecessary to consider yaw, thus further simplifying the situation.

Although the original geometrical construction methods are simple too, they are not suitable for use with a computer, and demand large scales, if acceptable accuracy is to be achieved.

BASIC RELATIONSHIPS BETWEEN GEAR AND VESSEL TRACKS

Including the effect of warp planform curvature

Location of the gear with respect to the vessel during manœuvres and in cross tide conditions is exemplified by two basic cases illustrated in fig 2 and 3 respectively. Figure 2 shows the situation in a turning manœuvre. (The notation used here is broadly consistent with the comprehensive notation used by B.H.C. in trawl gear investigations). W_g is the point midway between the otter boards. In the turn to starboard shown, water flow across the warps causes them to bow out in planform. The load in the starboard warp falls and that in the port warp tends to rise, and the starboard warp takes on a much more bowed shape than the port warp, to the extent that the two warps can cross, at least in the more severe manœuvring conditions.

Though this warp asymmetry can be neglected in very simple first order consideration of the problem, it becomes of significance in any detailed study and, for example, explains differences between the turning behaviour of trawls on the bottom and in midwater respectively.

Figure 3 shows a different type of situation, in which the aim is to tow the gear along a specified sea-bed

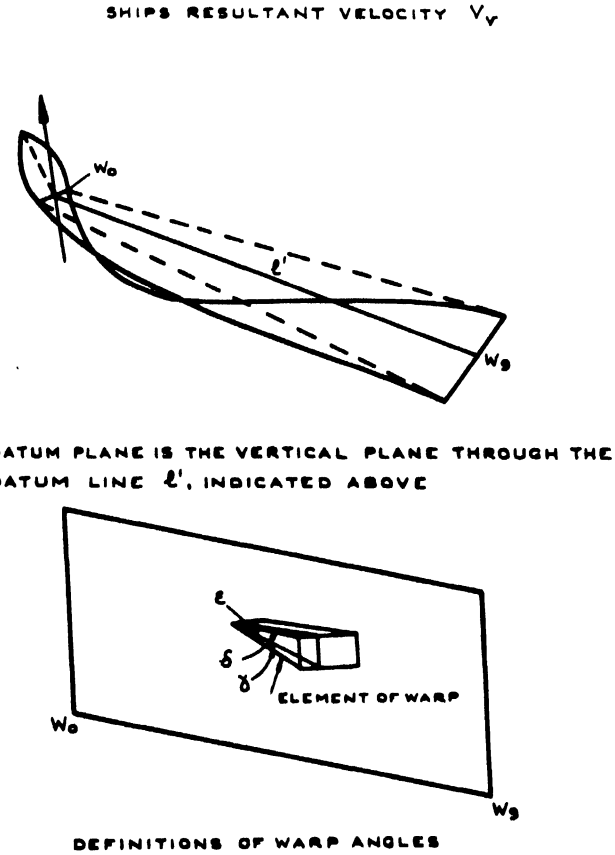

Fig 2. Asymmetry of warp planform shape during a turn

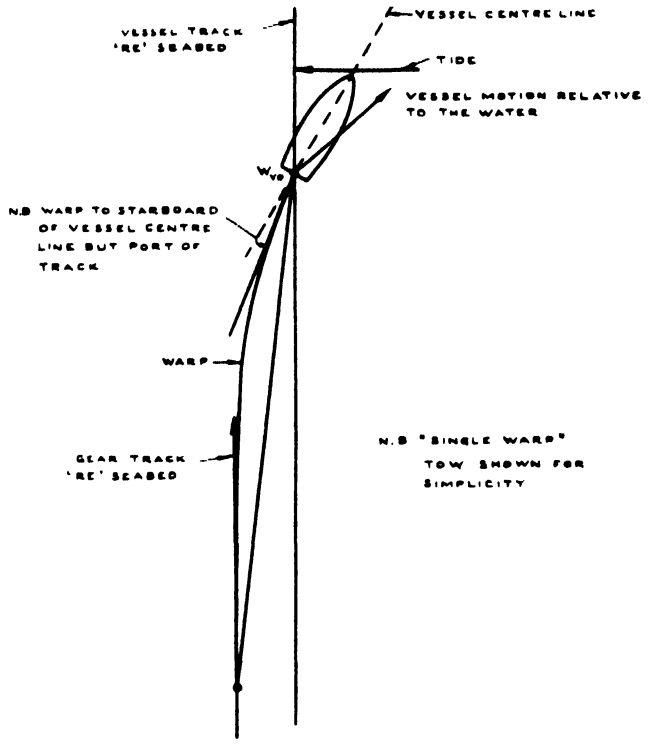

Fig 3. Warp curvature effects when towing along a straight line on the ground in cross tide conditions

track in the presence of a cross tide. The situation has been simplified by assuming that a single warp connects the gear to the ship, but the diagram shows clearly the importance of warp curvature. Although the gear lies to port of the vessel track relative to the sea-bed, nonetheless the straight line joining the vessel to the gear lies significantly to starboard of the vessel centre-line. The direction of motion of the vessel relative to the water is to starboard of its centre-line, but its direction of motion relative to the ground is to port of the centre-line. This situation can be analysed and understood only when proper account is taken of the effects of warp curvature both in planform and in elevation.

Referring to fig 4, it is convenient to define vessel and gear tracks by the horizontal motions of two points:

(a) The vessel point W_{vo}, which is at the stern, midway between the warps of a sterntrawlers, but at the warp block of a side trawler.

(b) The gear point W_g which is midway between the attachment points of the starboard and port warps to their respective otter boards.

When studying the detailed force and moment balance on the vessel, to determine helm or other control requirements, it is usually more convenient to define the track of the vessel by a point more centrally located within its planform. Such a track will differ somewhat from that of W_{vo}, and the two tracks will oscillate about one another if the vessel has a periodic yawing motion. However, by defining the vessel track as that of W_{vo}, for the purposes of relating the vessel and gear motions, complications of ship control are avoided, at least at this stage.

The diagrams of this paper will usually show the gear behind or to starboard of the ship, since large lateral displacements to port bring the warps of a conventional starboard fishing side trawler against the hull, and are undesirable. Thus the turns made are to starboard, and angle sign conventions are chosen accordingly.

When turns to port are considered, they can be treated as mirror images of the cases shown here.

The line joining the starboard and port warp to otter board attachments will not, in general, be precisely

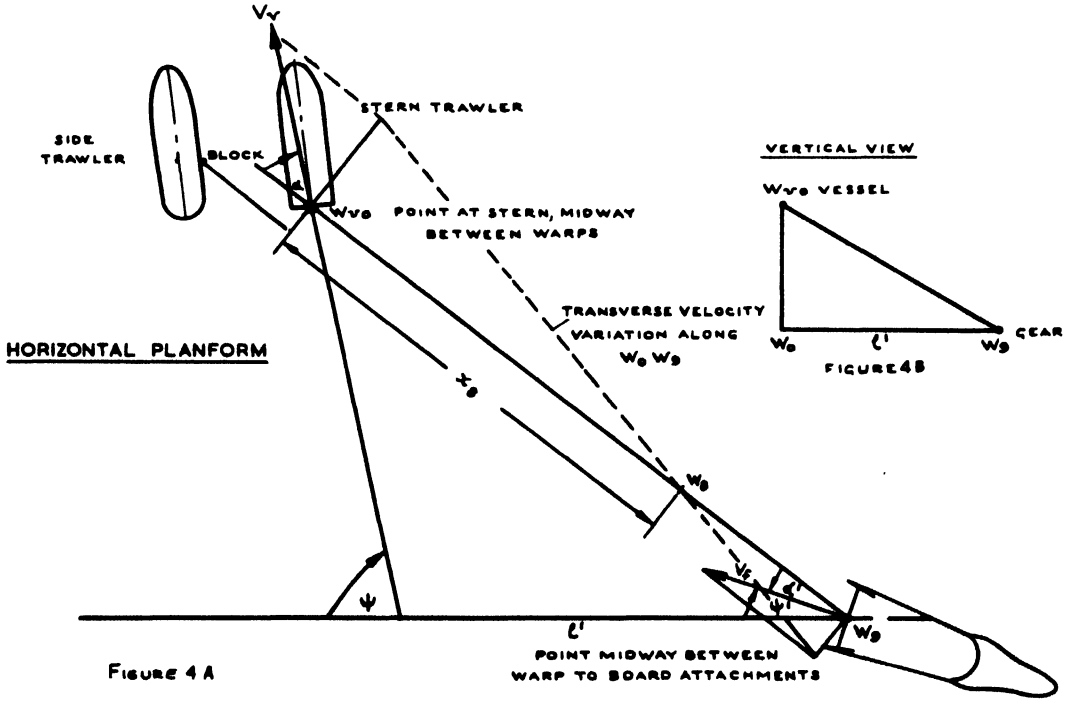

Fig 4. Definition of vessel and gear points W_g and W_o whose tracks are to be considered

perpendicular to W_{vo} W_9, but detailed study of the geometry of the board-bridle-net system (see Crewe, 1966, section 4) shows that only quite small asymmetry is possible if the gear is to remain in a good fishing configuration.

We shall refer to W_o, the projection of W_{vo} on a horizontal plane through the gear point W_9. The horizontal length between the vessel and gear points W_o W_9 will be called $\acute{e}$. The general motion of any point on W_o W_9 can be specified by the motions of its two end points. These will, in general, have velocities that are inclined to the direction W_o W_9. The vessel motion can be in a direction that is at a large angle α to this direction, but the gear motion will usually be at quite a small angle, α'. If there is no tidal velocity gradient down the warp, the transverse component of water velocity across it, due to turning, will vary linearly, as shown by the dashed line in fig 4. There is a point W_8, located on the line through W_o and W_9, and either between or outside these latter points, at which the transverse velocity component is zero. The horizontal distance of W_8 aft of W_o is called x_8, and its position is such as to give α' a satisfactory value.

In previous work (using geometrical constructions) it has been assumed that $x_8 = e'$ so that the gear moved directly towards the instantaneous position of the vessel, but this restriction is unnecessary, and the evaluation of representative cases (British Hovercraft Corp., 1970) shows that due to warp curvature x_8/e' depends upon α and varies between about 0.9 and over 1.2. In the latter case, for instance, the point that moves directly towards the vessel is 20 per cent of the vessel to gear length, aft of the otter boards.

It is clear that the value of x_8/e' varies during a manœuvre, and methods of allowing for this have been formulated, but in the examples of the present study constant values of 0.90, 0.95 or 1.0 have generally been used.

Returning to fig 1, a comparison is made between geometrical constructions and calculations for determining the gear track appropriate to a particular vessel track. An x_8/e' of 0.9 has been assumed throughout. Cases 2 and 3 in this figure give two different methods of geometrical construction. In Case 2, a series of equal steps along the gear track are taken, whereas in Case 3 equal steps along the vessel track are assumed. There is very little difference in the results from the two methods. Furthermore, they both very closely resemble the calculated solution, which is shown in Case 1. It is, of course, calculated cases of the latter type that are of interest in the present paper, since only they can be obtained sufficiently quickly and accurately in operation conditions to be of use in fish interception.

It may be observed that the vessel track chosen in the present case consisted of a circular arc blending into a straight line. At the start the gear is lying well to the port side of the vessel track, as the result of a previous manœuvre. During the time the vessel proceeds along its circular arc track the gear closes in towards it, crosses the vessel track, and would then move considerably inside the latter, as shown by the dashed line, if it were not that at this point the vessel starts to move in a straight line. Due to the change in the mode of vessel motion there is some discontinuity in direction in the gear track, after which it proceeds to subside towards the straight line track that the vessel is following. This confirms the common-sense view that, irrespective of previous manœuvres, if the vessel proceeds far enough in a straight line, the gear will ultimately line up behind it, or on a parallel track, depending on cross tide conditions.

RESULTS OF SOME FULL-SCALE STEERING TRIALS

The White Fish Authority (W.F.A.) have carried out some limited turning trials on a 65 m sterntrawler towing the Granton gear. From a straight steady track, the helm was set to a constant angle and vessel heading and speed and warp angles and tensions at the vessel were measured against time. Unfortunately a two component log was not available so that it was not possible to take sideways drift into account when constructing the vessel track.

With this limitation the trawl track was obtained by geometrical construction, assuming that the trawl followed in a straight line to the vessel at each stage (i.e. $x_8 = e'$, W_8 coincident with W_9). The result, for a starboard turn made with 10° helm is shown in fig 5A. It should be noted that the radius of the vessel turn is greater than the distance between the vessel and the gear. Under these circumstances the gear moves along a slow spiral track towards a terminal circle within the vessel turning circle.

It is worthwhile now considering the behaviour of the trawl during this turn in terms of the measured quantities. If the effect of warp curvature is ignored, it is plausible to assume that the angle of the taut warp as it leaves the vessel will nearly enough give the direction of the trawl. Using the same vessel track the trawl constructed from the measured angles of the taut (port) warp is shown in fig. 5B. It is immediately noticeable that the trawl track appears to be of an oscillatory nature. This effect might only be apparent and be due to the limitations of accuracy of the measurements. However, if such oscillations do occur during a turn, this could be a significant factor when trying to take the trawl through a target and suggests that the dynamics of the trawl may need careful study.

If a mean track through the oscillations is taken it will be seen that in the later stages of the manœuvre this lies closer to the vessel track than does the trawl track constructed by the "straight line" method of fig 5A. There are several factors which would account for the discrepancy between the two trawl tracks.

The three most likely possibilities are a drift angle imposed on the vessel by the offset warp loads, curvature of the warps due to the hydrodynamic loads imposed in the turn and, finally, a "tide" in the water at the surface relative to the water around the trawl. The first two may be considered in terms of their effect on the "taut warp" track, and the results for 5° leeway angle and 5° warp curvature are shown respectively in fig 5C and 5D. These two angles are considered to be likely maxima that might have been experienced in the conditions pertaining in the trials.

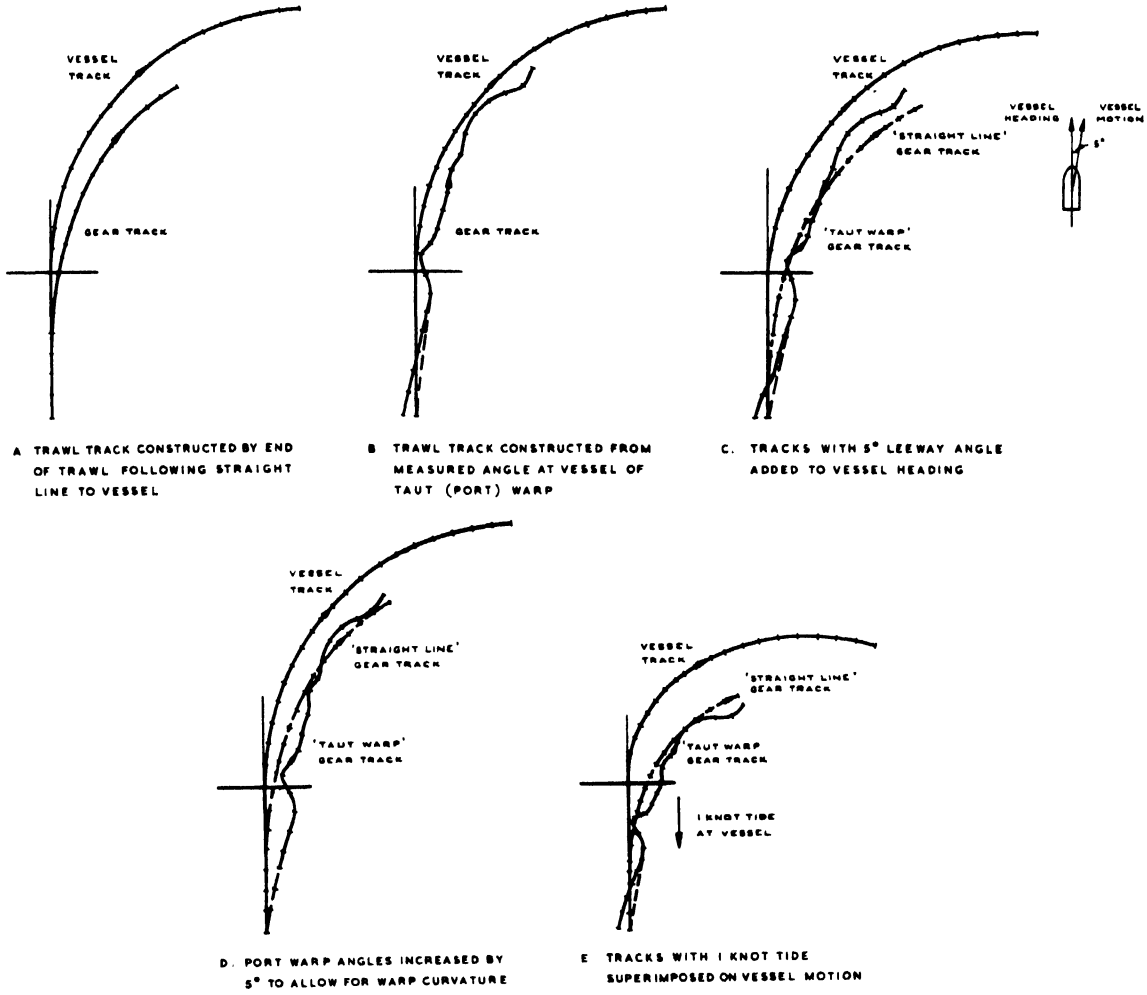

Fig 5. Graphical constructions of trawl tracks from limited full scale trials data

It can be argued that a tide other than one along the vessel's initial heading would be manifest in asymmetric warp loads during the straight steady run. Since this was not apparent a 1 kn tide along the vessel's initial heading has been assumed. All tracks are changed by this and the resulting "straight line" and "taut" warp tracks are compared in fig 5E.

It will be observed that in all these cases there is some improvement in correlation but there is nothing to indicate which of the above mentioned effects offers the proper explanation, and it is possible that a true trawl track would result from a combination of smaller contributions from each of them.

One obvious difficulty in examining these trials results in the lack of any direct measurement of the position of the trawl relative to the vessel. This means that the tracks shown in fig 5 have to be judged by their plausibility, and this is unsatisfactory for a full appreciation of the factors involved. It is therefore very desirable that in further full-scale trials some means should be available for locating the trawl in relation to the vessel. This could possibly be done with a special sonar device although in the future one would expect a fish locating device of suitable range and which could scan through 360° to provide the required data. Nevertheless it is provisionally concluded from the above discussion that the theory of this paper is in acceptable agreement with full-scale trials, insofar as this can be judged from available data.

SOME SPECIAL CASES OF VESSEL AND GEAR TRACKS OF PARTICULAR PRACTICAL IMPORTANCE

Some comments on the general situation will be made first. When a vessel is running free it does not enter a turning circle instantaneously, but instead moves along a rather complex track comprising a transitional portion which first swings away from the intended circle and then spirals on to it, as illustrated in fig 9A. This behaviour may also occur to some extent when towing but there was not sufficient full-scale trials data available to decide the details. Therefore, in this paper it is usually assumed that a vessel can both enter and leave a constant radius turn without having to traverse transitional portions of track. Then two simple manœuvres are considered to be of particular importance. In the first the vessel turns in a circle, and in the second the vessel comes out of the turn and continues in a straight line. Most practical manœuvres can be considered to approximate to

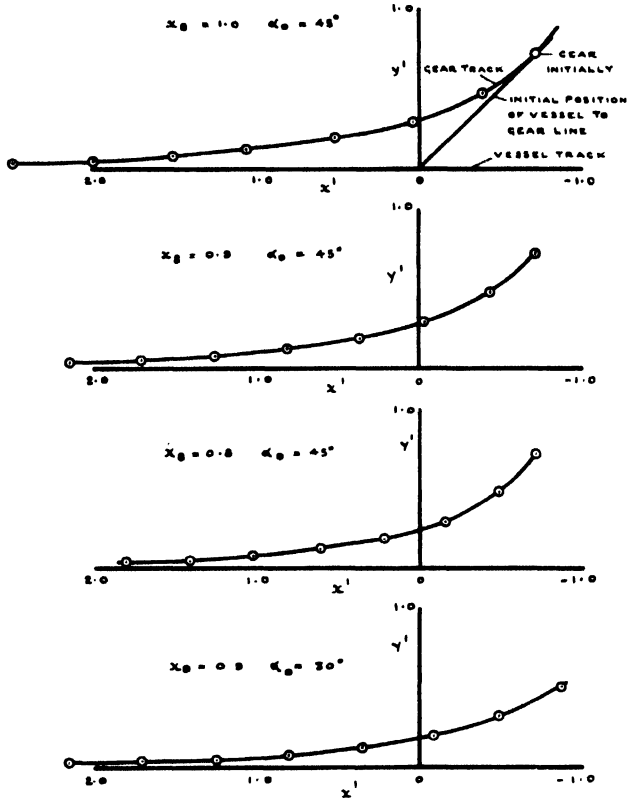

Fig 6. Straight vessel track

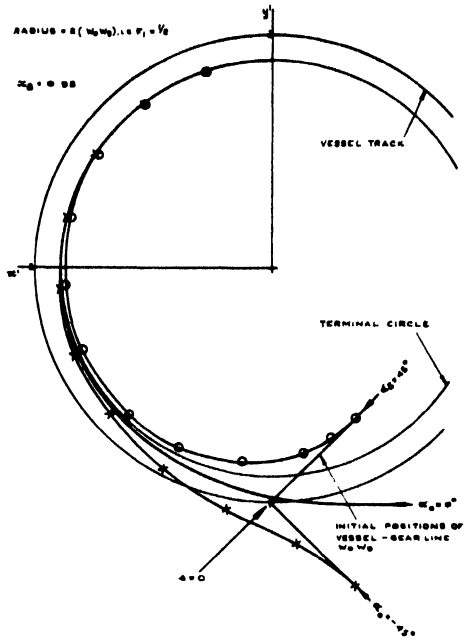

Fig 7. Circular vessel track of radius greater than vessel—gear distance $W_0 W_g$

combinations of these two, although where tight turns are required to intercept the target, straight line segments of track may not occur. On the other hand, where moderate turns would suffice, there may be an advantage in initially executing a tight turn and then proceeding towards the target on a straight track. This allows equal freedom to turn to port or to starboard during the final approach to the target.

Various plots of calculated vessel and gear tracks of particular practical importance will now be discussed in turn.

e', the horizontal distance between the vessel point W_0, and the gear point W_g, will be taken as the unit of length, and x_g will be assumed constant in any particular plot.

The simplest general manœuvre is that of pulling the gear back on to a straight line by navigating the vessel in a straight line. Various cases are shown in fig 6. In the top three, the line joining the gear to the ship was initially at 45° to the vessel track, as the result of a previous manœuvre. In the fourth, the angle was only 30°. In all cases the gear comes nearly enough on to the vessel track when the length traversed is about three times the distance of the gear to the vessel. For example, fishing in 100 fm of water, with 300 fm of warp aft, a distance of about a nautical mile would have to be traversed. This may be of practical interest in mid water, but the fish finder range for bottom fish is at the moment only about 100 fm.

Figure 7 shows the case when the vessel turns steadily in a circle of relatively large radius. Whatever the initial position of the gear relative to the vessel, the gear track spirals on to a terminal circle, which is not the vessel track circle but is concentric with it, and always of smaller radius. In the case shown the radius of the vessel track is twice the distance from the vessel to the gear, and the terminal gear track circle has a radius of 1.76 times the vessel to gear distance, or 88 per cent of the vessel track radius.

Figure 8 shows the situation when a vessel moves in a circle whose radius is less than the distance to the gear. In the particular cases shown the radius is in fact half the distance, and initial angles of vessel to gear line of 45° to port and starboard of the vessel track are pictured.

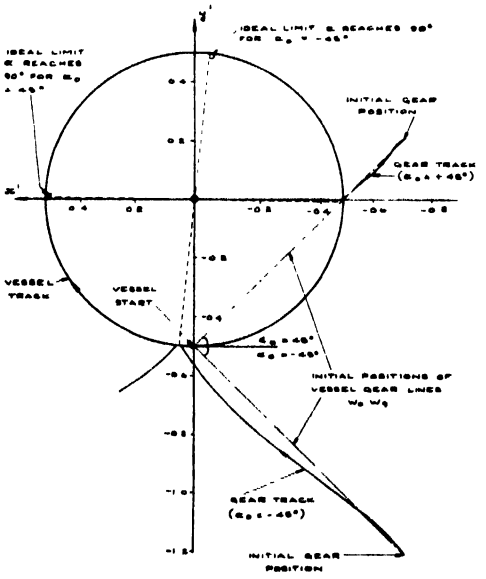

Fig 8. Circular vessel track of radius less than vessel—gear distance $W_0 W_g$. Radius $W_0 W_g / 2$—i.e. $F_1 = 2\ x_g = 0.9$

Because of the particular vessel track radius chosen the gear tracks approach and touch the vessel track, at which point the gear is collapsed because the line from vessel to gear is at 90° to the direction of motion of the vessel. This happens when the vessel has changed heading by just over 90° and just over 180° for the starboard and port initial angle cases respectively. Beyond 90° the diagram shows continuations of gear tracks which could only occur if the vessel and gear were joined by a rigid link, and so are not of practical interest. The above type of tight turn behaviour is supported by full-scale trials at 20° helm angle. Thus care must be taken, in theoretical track evaluations of sharp turns, that conclusions should not be drawn from conditions where the gear would in practice be collapsed.

Figure 8 and 9 together illustrate that it is not possible to turn the gear steadily in a circle whose radius is significantly greater than that of the vessel. This is because the angle between the direction of motion of the gear and the line $W_o W_g$ joining the vessel to the gear is, in practice, small or negligible. It therefore follows that for steady fishing conditions, the radius of turn of the vessel must be appreciably greater than the distance from the vessel to the gear. The only way to overcome this basic limitation is to supply some sort of side thrust to the gear so that its direction of motion can be at an appreciable angle to the line to the vessel. Such a side thrust may sometimes occur in practice, due to the otter board digging in to the sea bed. There is some evidence of this happening in turning trials in which 20° helm angle was applied.

As already mentioned, fig 9 shows a more complex application of the theory to a characteristic vessel turning manœuvre when running free, in which it passes through a transitional region of advance and transfer before reaching a steady circular track.

The advance and transfer portion of this vessel motion can be represented by various mathematical expressions, and, assuming that it is also relevant to towing conditions, corresponding gear tracks can be calculated, as illustrated in fig 9B. Some full line gear tracks are given in which the distance from the vessel to the gear is about the distance of the ship turning circle diameter. In these the gear collapses as it comes into the actual area of the vessel turn. In the chain dashed cases, however, the distance from the vessel to the gear is only one-third the vessel turning circle diameter, and then the gear follows after the vessel in an interesting manner—first of all moving to port of the vessel track and then crossing inside it.

The "polynomial" type mathematical expressions from which the examples of fig 9B have been obtained can also be used to study gear tracks due to rather complex vessel tracks, that may occur when fishing along a contour. Oscillatory tracks may also be required in such circumstances, see the discussion of fig 11 below.

Figure 10 shows an alternative solution of the equations of vessel and gear motion which represents not only the advance and transfer portion of a turn but also the vessel terminal circle, and in this case the gear also reaches a terminal circle of rather smaller radius than that of the vessel.

Figure 11 shows a very different situation in which the vessel proceeds in an oscillatory course. In the case illustrated the vessel motion direction is oscillated rapidly by swinging the helm over to a large fixed value and then holding it until the vessel heading is changed by a chosen "check angle", after which the helm angle is changed to an equal but opposite value, and so on. In fact, variation in vessel heading between about $\pm 20°$ was represented, as this is appropriate to the *Kempf* manœuvre type of vessel trial for determining ship manœuvring characteristics. It is most interesting to see that the magnitude of

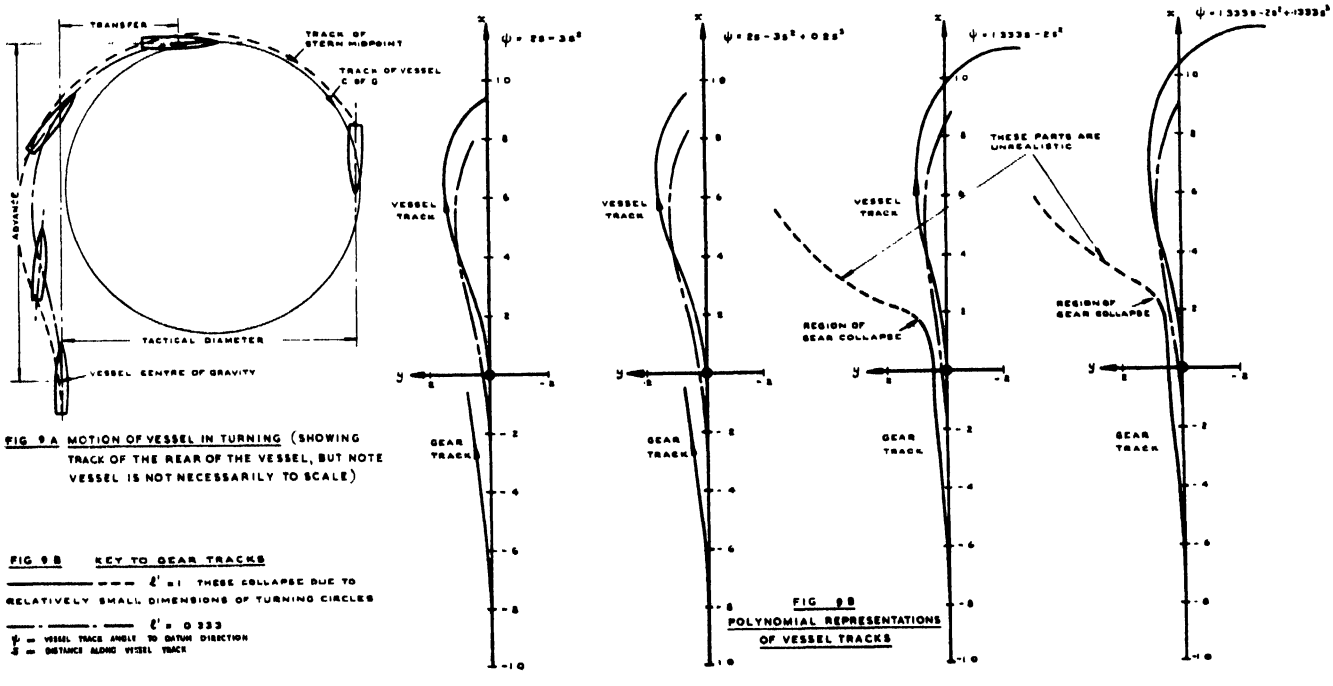

FIG 9A MOTION OF VESSEL IN TURNING (SHOWING TRACK OF THE REAR OF THE VESSEL, BUT NOTE VESSEL IS NOT NECESSARILY TO SCALE)

FIG 9B KEY TO GEAR TRACKS

——— — — — $\ell' = 1$ THESE COLLAPSE DUE TO RELATIVELY SMALL DIMENSIONS OF TURNING CIRCLES

——·——·—— $\ell' = 0.333$

ψ = VESSEL TRACE ANGLE TO DATUM DIRECTION

S = DISTANCE ALONG VESSEL TRACK

FIG 9B POLYNOMIAL REPRESENTATIONS OF VESSEL TRACKS

Fig 9. Some vessel track segments that are represented by a polynomial expression for S in terms of ψ—the 'advance' portion of a turn

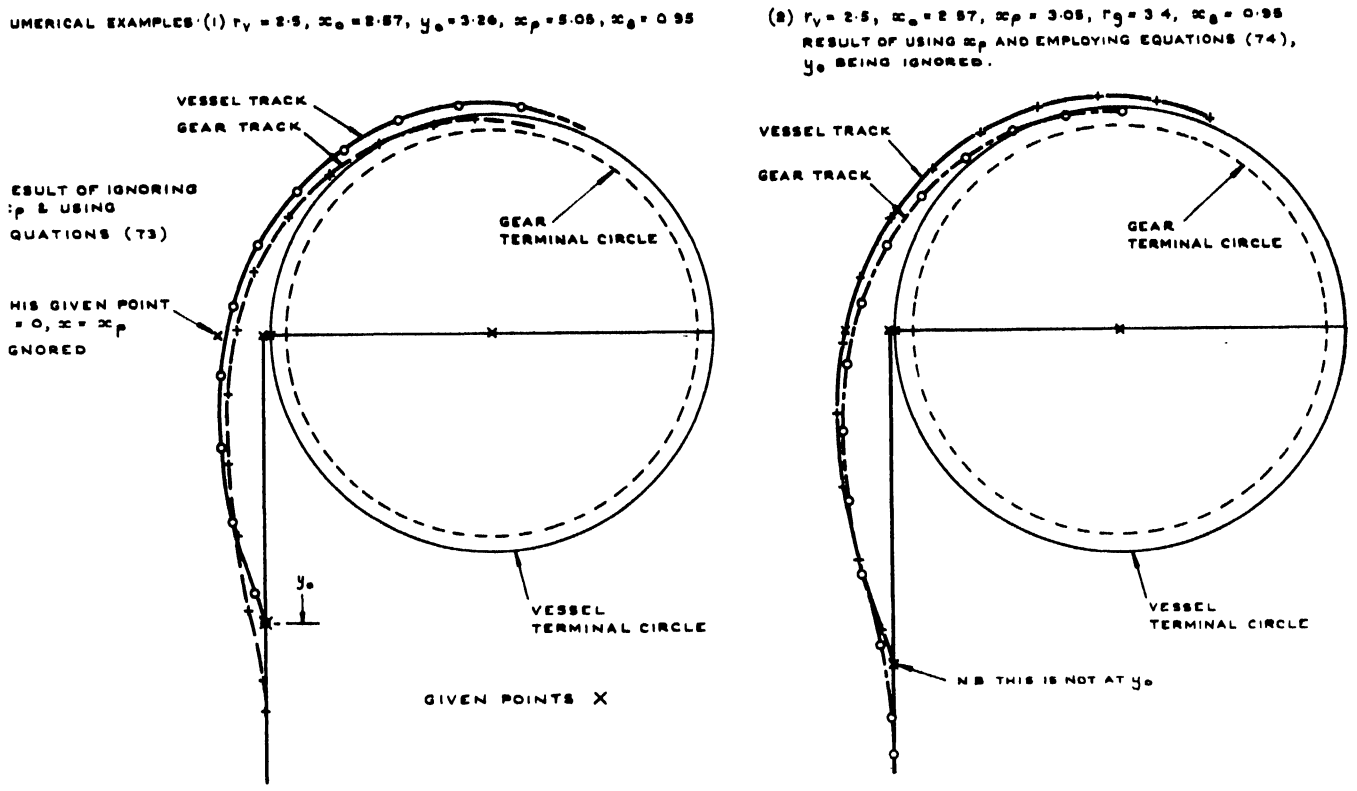

Fig 10. Computation of vessel tracks that spiral down to terminal circles

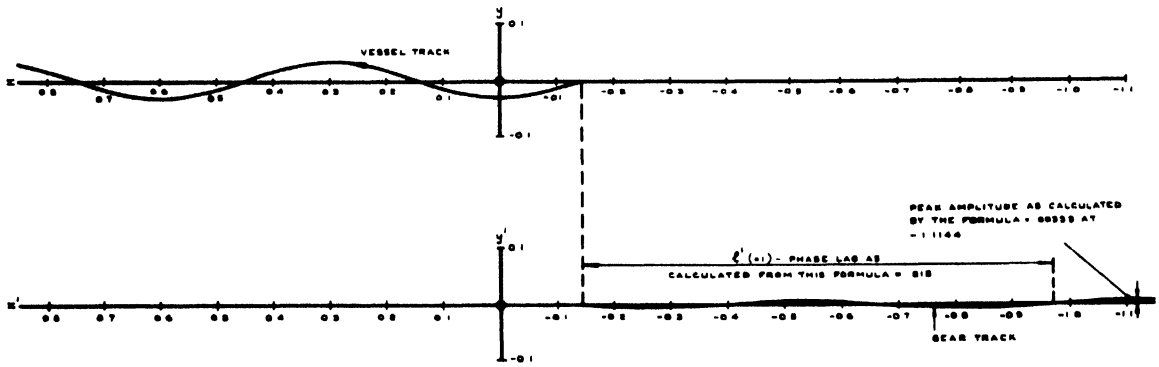

Fig 11. Oscillatory vessel track due to application of large helm angles. $A = \frac{1}{3}$, $a = 0.6$, $x_g = 0.95$. Distance along track between peak amplitudes of the same sign = 0.6 (vessel—gear distance, W_0W_0)

oscillation of the gear track is very small, being only about 10 per cent of that of the vessel track. In another case, not illustrated, the same "check angle", but much smaller helm angles, were assumed, the calculated oscillation was considerably slower, and the gear track then had an amplitude of oscillation of about 65 per cent that of the vessel, since it had time to respond.

The practical interest of this particular example is that it is hoped that *Kempf* manœuvre type trials on a trawler towing a gear will be of use in determining the general manœuvring characteristics of a trawler when towing from which full turning behaviour can then be deduced. The smallness of the gear oscillation when the vessel oscillation is rapid, supports the view that this should be a promising approach. Furthermore, the information obtained should allow the prediction of helm angle variation necessary to achieve any prescribed vessel track, and thus would form one of the main building blocks required to establish scientific procedures for achieving trawl fish interception.

It is provisionally concluded from an examination of the examples of fig 6 to 11, that the mathematical technique underlying this paper is of great promise for representing realistic manœuvring tracks of vessels that are towing gears, and for predicting the corresponding gear tracks. When sufficient trials data is available it is anticipated that the technique will be able satisfactorily to represent and exploit the empirical situation then presented.

In the above procedures, vessel tracks that are often

of simple form, such as straight lines and circular arcs, have been specified. The corresponding gear tracks that have been deduced are usually more complicated, often considerably so, comprising spirals leading to terminal circles, and so forth.

It might be thought that instead simple gear tracks should be specified and the basic equations rearranged to determine corresponding vessel tracks. This has been attempted but unfortunately the results usually contravene warp curvature restrictions so that they could only apply if the gear were fitted with a "side thruster" or had ploughed into the sea bed or collapsed in such a way that it could sustain a considerable lateral component of pull from the warps without lining up to the direction of tow. Therefore at least when using trawls of basically traditional type it is necessary to specify vessel tracks and to deduce gear tracks rather than to proceed the other way round.

FISH INTERCEPTION PROCEDURES

This section of the paper describes the results of using the equations for vessel tracks and the corresponding gear tracks, that have been illustrated in section 5, to determine the vessel tracks required to intercept fish that have been sighted at prescribed locations. Cases of fish stationary, and of fish moving relative to the ground are examined. Simple vessel navigational procedures are possible but may lead to the trawl missing the fish by an unacceptably large margin. With a more complicated technique it can be ensured that the trawl passes through the fish even if the range at first sighting is not very much greater than the distance from the vessel to the gear.

The simplest situation is that shown in fig 12. When the vessel is at O and travelling along the straight line OX, stationary fish are sighted at points such as F_1', F' etc. The vessel brings the gear through these fish by turning steadily in a circle from O that passes beyond the fish in such a way that the gear itself passes through them. The short black lines from the fish location F_1' etc., join them to the corresponding vessel positions, on the appropriate vessel circle tracks, at interception. It will be seen from $\hat{F}'$ that fish can be caught inside a circle whose radius equals the distance from the vessel to the gear, provided that the vessel turning circle required is not so extremely small that the gear collapses. Some of the results shown are tabulated below, the distance between vessel and gear being taken as unity in every case.

Fish at	$\hat{F}'$	F'	F_0'	F_1'	F_2'
r, the distance of fish from starting point, o	0.781	1.414	2.062	2.658	3.808
$\theta°$, the angle of r to initial linear track of vessel	39.8	45.0	1.405	48.8	66.8
Vessel track radius r_v required for interception	1.205	1.376	5.069	1.983	2.20

Further cases, not illustrated here, examine the interception of fish that were sighted abaft the vessel beam but sufficiently far away for the vessel to be able to turn back towards them without collapsing the gear. This type of manuœvre may require fish finders of greater range than are needed by the cases of fig 12. Furthermore, search through 360° or thereabouts is then essential. Further work should be undertaken to find how much of the area within the unit circle of fig 12, is inaccessible in practice, and how the general scope of the interception process depends upon the ratio of fish detection range to vessel-gear distance.

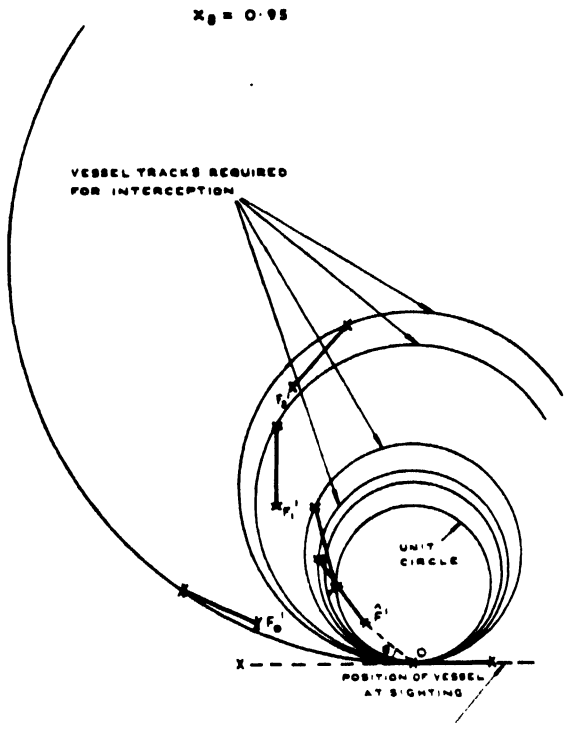

Fig 12. Interception of stationary fish by turning the vessel in a constant radius path that brings the gear to the required position

If the fish are moving it is possible to determine their speed from a number of sightings and calculate the radius of the vessel turning circle that will lead to an ultimate interception at some interpolated or extrapolated point. An example has been evaluated, which uses the data of fig 12 again. It was assumed that the fish moved along a straight line F_0' F_1' F_2' at a steady speed. Results are shown in fig 13. The base scale gives the distance moved by fish in fathoms, while the left-hand and right-hand verticals give the time from the point o to interception in minutes, and the required radius of the vessel track in fathoms. The vessel was taken to be moving at 3 kn and the distance from vessel to gear was 140 fm. The following results were obtained:

Fish velocity, kn	1	1.4
Vessel track radius in fm, required for interception, assuming vessel to gear distance = 140 fm	315	245
Times to interception, minutes	11	15

It is important to note that if the fish had been swimming appreciably faster than 1.4 kn they would

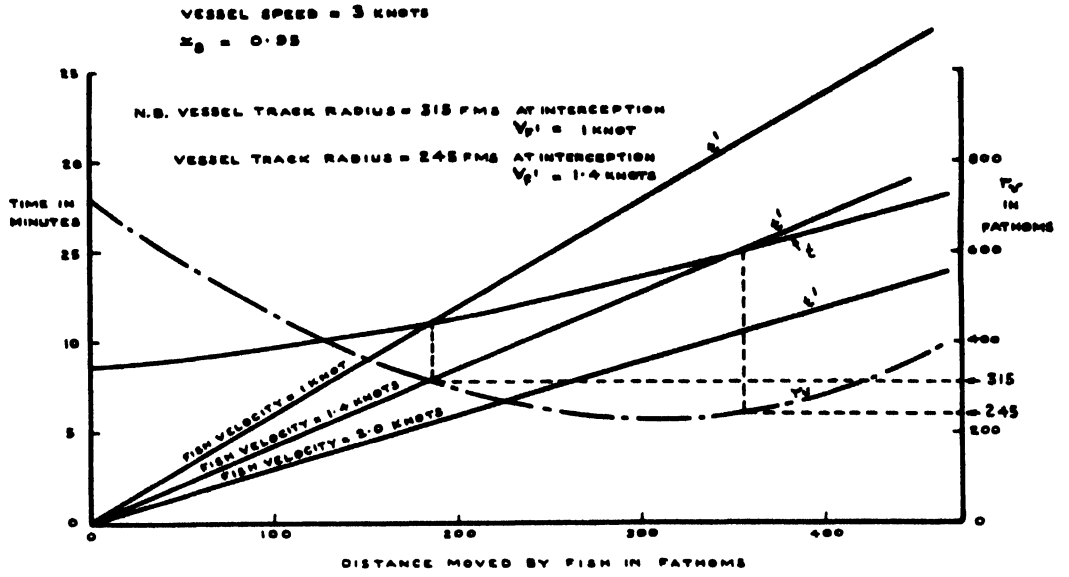

Fig 13. Times and vessel track radii required to intercept fish moving steadily along a line F_0^1 F_2^1 of figure 11

have escaped, since the t' curve appropriate to the fish would no longer have intercepted the vessel t curve at any point. This is illustrated by the "2 knot" lowest fish line of fig 13.

After making the above simple calculations, more suitable tactics for use in practice were sought. Two are described below: the first proved to have limitations, but it is described in detail because of the importance of the issues that it raises. The second is very promising, but ideally requires the gear location to the vessel to be instrumented.

It was considered that a suitable tactic would be to proceed in a series of steps, a new sighting being made of the fish at the beginning of each step and the course being changed as appropriate. This type of step-by-step interception may be referred to as updating. In the single step example of fig 12 the horizontal distance between vessel and gear was 140 fm, sighting at more than twice this distance, i.e. about 300 fm, being assumed. The interception time was 11 min. By contrast the programmes for calculating the best turning radius required in any step take less than 1 min to run on e.g. an Elliott 4120 "6 microsecond store speed" computer. Thus updating techniques are quite feasible when a small computer is carried aboard. The above quantitative conditions are, however, only appropriate to mid water fishing, with the present limited "on bottom" range of fish finders.

It was decided that the track increment or "step" between updatings should comprise a relatively rapid turn by the vessel at constant speed and radius until its directions of motion passed through the target position predicted for just before the next updating, followed by a straight line motion of the vessel until the next updating. The reasoning was that as in fig 1, the gear would come back towards the vessel track during the period when the latter was moving straight and the technique would give the greatest scope for track modifications at updating. The vessel was therefore navigated in a series of steps in each of which it first turned, at the same radius every time, and then proceeded straight. Results are shown in fig 14 for a case in which the distance moved between updatings was one-third that from the vessel to the gear. The motion of the fish was chosen to be rather random since it was a predicted motion relative to the vessel and was intended to cover not only motion of the fish but any failure in the vessel to navigate along the required track. The final step in which the vessel is initially at not more than one-third the vessel to the gear distance from the fish requires special treatment, and two possibilities are shown on the left-hand side of the figure. If the fish are so located that the standard radius of turn will not bring the vessel heading into line with the target before it is passed, then after passing the vessel may either continue in a straight line or go around a circle of standard radius containing the fish. A final increment of vessel motion is then necessary to bring the gear to the neighbourhood of the fish and during this the vessel proceeds in a straight line.

The two approaches described above are illustrated as Cases A and B on the right-hand side of the figure. It will be seen that changing the last step alone makes a big difference in the amount by which the gear misses the fish—in a ratio of almost two to one. However, neither procedure is regarded as altogether satisfactory, and this is because the straight line portions of each step were too short to pull the gear in behind the vessel during any one of them, whereas each circular arc segment caused a gear displacement away from the vessel track.

A further difficulty in the case shown was the change in direction of relative movement of the fish during stages 4 to 6 which would not have been predicted from the movement at earlier stages, and without which the given gear tracks would have passed much closer to the target.

On the other hand, the gear has considerable dimensions, and the fish will be spread over an area, in the type of aimed trawling under consideration. Taking the step distance in fig 14 as about 50 fm, the actual miss distances shown would have been 30 fm and 50 fm to the centres

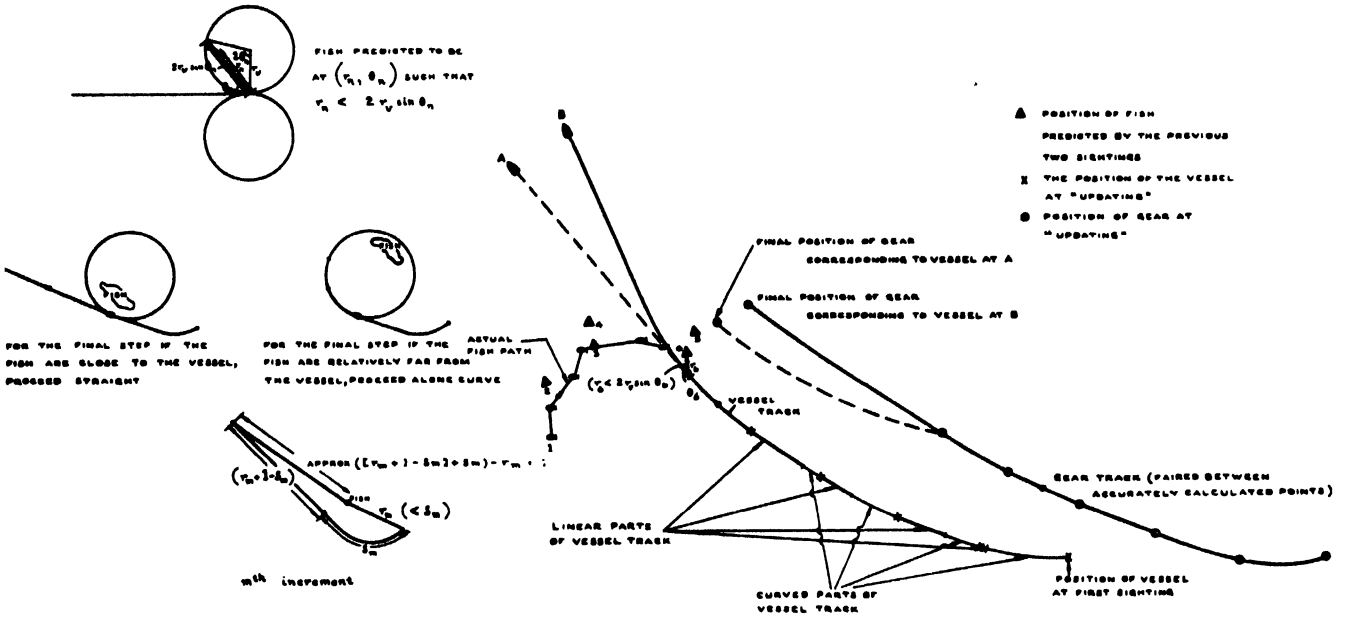

Fig 14. Interception by updating the sighting data and vessel track requirements at frequent intervals

of the schools, so that actual catching probability would have been relatively high.

In future work, interception diagrams should show both school and gear dimensions, so as better to judge the likelihood of kill. For updating a 360° scan, after the vessel passes the fish, is desirable.

Note that in case A the gear track is markedly discontinuous at the beginning of the step before last. Such discontinuities are unavoidable if the vessel changes from a straight to a circular arc track, without a transition stage, and occur also within the earlier steps but have been faired there. They might be a source of gear instability or collapse, though in practice finite length transitions in the vessel track from straight to turning conditions may smooth out gear track discontinuities of direction. In further investigations of updating techniques, allowance for a given vessel and gear of the transitional vessel track between making a helm change and reaching a constant radius of turn will thus be of particular importance.

The not altogether satisfactory nature of the above results is regrettable, because pointing the vessel at the target can be achieved with more precision and certainty than pointing the gear at the target. Gear pointing accuracy is of course improved if the gear position also is being recorded as, for example, by using a fish detection equipment that has an all-round scan, or by mounting a fish detection equipment on the gear. Otherwise estimation of gear position using the theory underlying this paper is necessary, even though sea bed obstacles and so forth may significantly affect actual gear tracks.

Turning finally to fig 15, the same predicted fish positions relative to the vessel at the end of each step are assumed but now the length of the circular arc portion of any step and the direction of turn are chosen to minimize the distance between the gear and the fish at the end of each step. The case shown may appear rather a simple one but it fully checks the method and achieves a "bull's eye" on the final predicted position of the fish.

The actual position of the fish can differ from the predicted position in a random way, and a probability area about the previous sighted position can be calculated. This is another possible refinement for further work. It is believed that development of the above "minimum distance" method, assisted by instrumental determination of gear position, from time to time during interception, should provide high probabilities of achieving a "kill".

CONCLUDING REMARKS AND FUTURE WORK

The work summarized in this paper establishes that the gear track appropriate to any given vessel track can be obtained by analytical methods suitable for programming in a computer. These methods seem sufficiently powerful

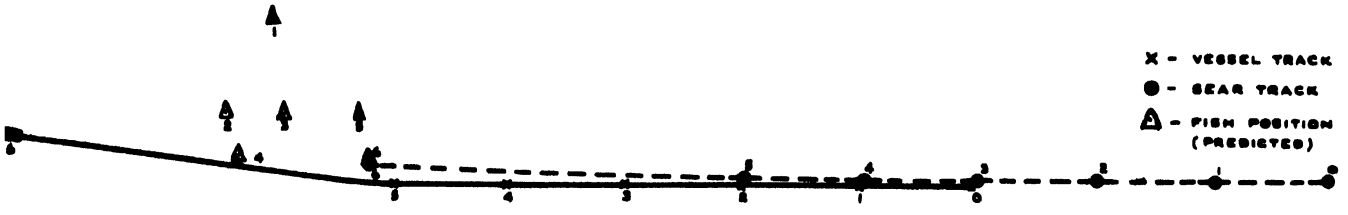

Fig 15. An estimation method for updating that minimizes the distance between the gear and the fish at each increment

to cover any likely case of practical interest, covering both bottom and midwater trawling.

Both simple and relatively complicated vessel tracks are satisfactorily treated. These include straight lines, circles, spirals down to terminal circles, advance and transfer transitions to terminal circles of the type free running vessels perform, and oscillatory motions such as those obtained in *Kempf* Manœuvre trials. Segments of tracks of different types can be combined and in all cases the corresponding gear track can be determined.

Attention has been given to "updating interception procedures" in which the vessel track is corrected at frequent intervals in the light of new information on the range and bearing of the target given by the fish detection equipment. Rather simple examples have been given involving vessel tracks which combine straight segments and circular arcs of constant curvature. Further strategies require to be explored using the techniques given here. Computer programmes have been written for this purpose.

As more trials data become available on the manœuvring characteristics of vessels when towing, the vessel tracks used in the interception theory can be made more realistic.

It is confirmed that tight vessel turns are critical from the point of view of gear collapse. However, such turns may be demanded by limitations in the range of current demersal fish detection equipment.

Furthermore, updating the interception procedure calls for continuous monitoring of the position of the target relative to the vessel. It is therefore desirable for the fish detection equipment to scan through 360° and have a range which is substantially greater than the distance between the vessel and the gear.

Forward scanning over a limited range and arc may well locate a target, but for most of the period during which the gear approaches the assumed position of the target the manœuvring would have to be carried out "blind".

Interception and sea bed track following techniques can be made much more precise and certain if the position of the gear relative to the vessel is instrumented. A fish detector with an "all round" scan and sufficient range would provide the necessary information. Alternatively a finder can be fitted to the gear, as has been used in the work of Dr. Schärfe.

Another possibility might be to design gears that require substantially less warp length in a given depth of water than those currently employed. This would permit the use of proportionately tighter turns and facilitate interception. Furthermore, the necessary changes in gear design would allow fishing in much deeper water for a given winch drum capacity.

More numerical examples of interception need to be evaluated to determine the gear collapse and vessel manœuvre limitations on successful interception. This will also involve special work on the amount of asymmetry that the board, bridle, net system can sustain under satisfactory fishing conditions. A basic requirement for studying this is to know the asymmetry of the warp pair in both planform and elevation shape. The necessary theory for doing so has been developed, and numerical examples evaluated. This work also shows that the gear does not, in general, move precisely towards the vessel at each moment of a manœuvre. The angle off is usually rather small but is taken into account throughout the present study. This was not done in previous methods using geometrical construction.

In midwater fishing, gear asymmetry during turning can involve differences in the depths below the sea surface between the starboard and port otter boards. This can be investigated by the above-mentioned warp shape theory, in conjunction with otter board force and moment equilibrium equations, that have been developed by the British Hovercraft Corporation.

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DISCUSSION

ESTABLISHED COMMERCIAL FISHERIES

Steinberg (Germany) Rapporteur: Among recent advances in trawling the development of one-boat midwater trawling is particularly noteworthy. When the second FAO World Fishing Gear Congress was held in London in 1963 this technique was still in an experimental stage except in the case of Japan's fisheries as mentioned by **Kristjonsson**. In the meantime, however, it has come into commercial use in quite a number

of countries where suitable trawlers with sufficient engine power are available. At present one-boat midwater trawling is conducted on a more or less commercial scale, for instance in Canada, France, Federal Republic of Germany, German Democratic Republic, Ghana, Great Britain, Japan, Poland, USA and USSR. Additional information from other countries also using this technique would be desirable. **Kodera** describes the midwater trawl used by the big sterntrawlers of his company (Japan) on a larger commercial scale. This net has a circumference of 936 meshes, meshsize 180 mm stretched in the front part, i.e. it is relatively small compared with nets elsewhere. Between the wings of the lower panels additional netting can be attached if desired to intercept downward moving fish schools. Obviously hydrofoil otter boards are employed exclusively in the Japanese pelagic trawling. Of the two types of netsonde the cableless version is considered to be the more advanced in the Japanese fishery and this type is predominantly used. Unfortunatley no description of one-boat midwater trawling in the Federal Republic of Germany was submitted. Therefore the comprehensive review of the development and the present state given by **Schärfe** (*Fishing News International* **1969**) mentioned before and **Muschkeit's** report on German midwater trawling, particularly on the so-called "super trawl", in *World Fishing*, may be referred to. Reprints of both are available here. In Germany one-boat midwater trawling is of particular interest in sterntrawling. Therefore all these vessels and, in addition also some of the bigger side trawlers, are equipped with such gear of the newest standard, including netsonde and sonar. One-boat midwater trawling in Germany is now a common fishing method which, for herring, is even more important than bottom trawling. Recently its importance seems to grow also for other species e.g. cod (*Gadus morhua*) and redfish (*Sebastes marinus*). In the beginning of the German development both two and four sideseam trawlnets were tested but now all are of the four sideseam type with narrower side panels. As already mentioned it is often considered more favourable, with regard to catching efficiency, to use large nets with correspondingly lower towing speed rather than smaller nets with high speed. On this basis the average size of the German one-boat midwater trawls has been increased year by year and the thus increased towing resistance was partly compensated for by the use of larger meshes in the front part of the net. It should be mentioned that this trend towards bigger nets is also found in some two-boat midwater trawl fisheries. However, the large nets are more expensive. For this reason the use of the extremely large pelagic trawls with an opening height and opening width of up to about 60 m in German commercial midwater trawling is still rather limited and medium size nets with a circumference of 1,600 to 2,400 meshes at bosom level (on the basis of 200 mm meshsize stretched) with an opening height of about 16 to 25 m are much more common. Hydrofoil otter boards of the Süberkrüb type are standard and no other types are used in Germany for midwater trawling. The size for medium size nets is 6 to 8 m^2 and for extremely large nets 12.5 m^2.

All German trawlers involved in midwater trawling are equipped with echo sounders, sonar and netsonde. Almost exclusively the netsonde with cable is used. It is considered that the wire connection is preferable, particularly in view of multi-netsonde equipment and the even more increased demands envisaged for the near future. There are no difficulties in handling the cable because the cable winches operate automatically.

From the West African coast **Dijkhuizen** and **Zei** report midwater trawling to be a very promising technique, particularly north of 12°N latitude. It is done both during day and night time, but fishing is better during the night. Catches consist mostly of sardinella, mackerel, carangids and bream. At present 10 of the 20 large Ghanaian sterntrawlers are using one-boat midwater trawls. **Raitt** and co-authors report on experimental one-boat midwater trawling off the West African Coast (UNDP/SF Regional Fisheries Survey) with nets of up to 1,600 meshes circumference at bosom level, meshsize 200 mm stretched. This fishery with a chartered trawler of 900 hp was quite satisfactory for sampling. A more commercial type midwater trawling in another UNDP/SF Project off Argentina is described by **Okonski** and **Martini**. Their midwater trawls are "square", i.e. they consist of four equal panels. Contrary to midwater trawling in most other countries, **Okonski** uses rectangular flat bottom trawl otter boards also for pelagic trawling. It would be desirable to hear more of his reasoning for this unusual practice. **McNeely** reports on quite successful one-boat midwater trawling developments in the USA (NE Pacific) where its adoption for commercial use is still limited for economic reasons. According to **Savrasov** the big USSR sterntrawlers use mostly four panel nets with narrower side panels and a headline length of about 38·5 m. The opening height of this net type is between 14 and 18 m. and the rigging is similar to that of the German gear. **Kudryavtsev** describes netsonde equipment from the USSR with and without cable, but it seems that the cable type is preferred and more common. According to **Calon** for one-boat herring midwater trawling in France four panel nets with a rigging very similar to that used by the German and Russian fisheries are employed. The nets have a circumference of between 1,400 and 2,000 meshes at bosom level (calculated on the basis of 200 mm meshsize stretched). Additional information is given by **Portier.**

The gap in the contributions regarding one-boat midwater trawling in other countries, such as the UK, Norway and Canada, should be closed during the following discussions, and this should include information available at FAO on experimental and exploratory application in developing countries.

Midwater trawling with two boats is usually employed by the smaller trawlers with comparatively low towing power. **In** view of the increasing number of small sterntrawlers means have been found to adapt the two-boat method to this type of boat. **Minnee** was concerned with experiments in the Netherlands through which a satisfactory solution was found which does not require any substantial changes in equipment. Recommendations to use the two-boat midwater trawl system in coastal fisheries off tropical West Africa are given by **Dykhuizen** and **Zei** and by **Steinberg.**

The catch of fish from the bottom up to about 10 to 20 m above the ground is of particular interest. It is however not always possible to cover this area satisfactorily with common trawls. Normal bottom trawls have too small an opening height so that they can only get hold of the bottom fish. Midwater trawls on the other hand, if the ground is rough, can only be used near the bottom and will then only catch the semi-pelagic fish. Consequently nets are required which can be towed directly on the ground but have such a large opening height that they can also catch semi-pelagic fish. In the development of trawl gear for such conditions two lines were followed, i.e. high opening bottom trawls achieved by increasing the size and modifying the design of normal bottom trawls, or combination midwater and bottom trawls. As described by **Kodera** and by **Nakamura,** in Japan the normal two panel bottom trawl was increased and modified by adding two additional triangular netting wedges to the upper wing and the front part of the belly. As a second step these four panel nets were further improved by adding two more netting wedges resulting in the so-called six panel bottom trawls which have an opening height of up to about 12 m if a kite is used. These two, four and six panel nets are used according to conditions in the Japanese fishery. **Nakamura** mentions in addition a so-called vertical twin body or two-floor trawl

which consists of two trawls, one on top of the other. The purpose is not only to achieve a high opening, but also to separate certain fish species during towing. All these Japanese bottom trawl types which are fished with big hydrofoil otter boards have full lower wings and it may therefore be questioned whether they are suitable for rough bottom. The relatively complicated construction of the six panel net and the two-floor trawl, may lead to difficulties with operation and repair. Commercial high-opening bottom trawls and semi-pelagic trawls from France are described by **Maucorps** and **Portier** and by **Calon.** The rig of this gear is very similar to that of the Breidfjord system and they are mormally fitted with a netsonde. Another French high-opening bottom trawl, but for smaller vessels of 150 to 400 hp is described by **Nédélec.** This gear is rigged differently, i.e. with three bridles, a danleno and a sweepline on each side.

The Japanese combination bottom and midwater trawls discussed by **Kodera** and by **Nakamura** seem to be still in an experimental stage.

There is a distinct tendency towards increased size of trawl gear. This leads to handling problems on board the vessels for the solution of which net handling devices are needed which, at the same time, could save manpower. This matter is discussed in the contributions by **Karger, Minnee** and **Kristinsson.** In **Karger's** opinion, net drums offer good possibilities for mechanizing the handling of large trawl nets, but other devices like powered blocks may also be suitable.

Goodlad (Canada) Chairman: In Canada there is a midwater trawl fishery for Atlantic herring with some 10 to 12 boats. Some of these are combination purse seiner/trawlers and others are converted scallopers or bottom trawlers.

They employ, basically, the German system with nets which have increased from 800 to 1,600 meshes circumference, meshsize 200 mm stretched and the vessels are from 90 to 115 ft in length with a few larger and the largest 150 ft. Some of the vessels are using net drums while others are conventional sterntrawlers. In some instances power blocks are being used for net hauling and pumps are employed by some for emptying codends.

More ships are now being converted for midwater trawling because of the general decline of ground fishing and it is hoped that they could also be used on other species than herring, such as sand launce or capelin. It will be interesting to compare the conversion of these vessels to that of the Scandinavian purse seiners.

Allers (Norway): I may complete the Chairman's statement on Canadian midwater trawling by giving an example of the efficiency of this operation.

A sterntrawler—158 ft, 1500 hp—operated last year with herring hauls of regular 50 to 75 tons. Maximum haul has been approx. 120 tons. Maximum production over 12 hours has been 600 tons, daylight fishing. Total production over the year's seasons was 20,000 tons of herring, mostly for meal but also for human consumption. A conventional 1600 mesh circumference, meshsize 200 mm stretched midwater trawl has been used. Difficulties were encountered with the larger mesh nets.

Noel (UK): I would like to bring up to date my description of the inshore pelagic fishery of the UK to the first FAO International Fishing Gear Congress in Hamburg 1957. This is almost exclusively a two-boat operation and carried out by inshore trawlers, mostly sterntrawlers of about 13 m. The reasons for using two boats are more or less economic because they lack sufficient horse power to tow a single boat trawl and by adding the two horse powers together and by eliminating trawl boards they are able to tow a modified Larsen trawl. This is mostly in shallow water and is another reason for using two boats as it is thought that a single boat causes the fish school to break up, and this is a bad thing. Fishing is mostly for sprats (*Sprattus sprattus*) which are found in very dense concentrations. They are not a very active fish and catches can be very heavy, as much as 7 tons in 10 minutes. Some of the sprats go for fish meal, others for pet food and a small quantity for human consumption. Ordinary echo sounders are used, but no sonar nor netsonde. Calculations of net depth is by good luck, judgment, experience and occasionally the broomstick method mentioned by **Schärfe.**

Parrish (UK): In addition to what **Noel** has just said about midwater trawling for sprat there is in Scotland a rapidly developing two-boat midwater trawl fishery for herring by side trawlers, 65 to 80 ft in length and 200 to 600 hp. The nets are standard four panel Larsen-type trawls. Some of the vessels now have sonar and some have netsonde.

Drever (UK): One-boat midwater trawling in the UK uses the German system with trawlers of 220 to 250 ft mostly with nets of 2200 meshes circumference (200 mm meshsize stretched) The fleet has reported reasonable success during the last two weeks off Norway. There is however a winch problem with hauling the gear for depth regulation. I am not sure whether this is alone due to inadequate winches or partly also to lack of experience of the skippers.

Juliusson (Iceland): I would like to say something about the Breidfjord trawl which was used on the cod spawning grounds of Iceland around 1950 to 1954. The gear is assumed to be well enough known so that it does not have to be described here. No additional auxiliary equipment was employed, only the old fashioned echo sounders of those days. During night time cod (*Gadus morhua*) gathers in big schools in midwater, and as there was no net depth measurement the simple technique was to vary the net depth arbitrarily by varying the towing speed. A man was stationed at the towing block to inform the skipper when the warps closed. We were getting up to 20 to 40 tons of big cod per tow and this was possible because during the night the spawning cod kept very still—we believe that it was in a vertical position with the head down—so that it had only to be scooped up. We were also catching saith (*Pollachius virens*) on the same grounds but not in such heavy quantities as cod.

Thorsteinsson (Iceland): Due to the well known changes in fish availability and distribution there is at present some interest in Iceland in midwater trawling for blue whiting (*Micromesistius poutassou*).

Schärfe (FAO): When midwater trawling for herring off Iceland we had difficulty in avoiding the blue whiting, which was spread out in thin layers over large areas during the winter. It is very easy to catch and almost any quantity could be taken. At the time, I suggested that some of the German trawlers working the midwater trawl should catch blue whiting and land them in Iceland, where the meal plants were idle at that time, but this proved to be against the law.

Jakobsson (Iceland): There were rumours in Iceland that in autumn 1968 German trawlers were making heavy midwater trawl catches of cod off NW-Iceland. For the benefit of the Icelandic fishing it would be appreciated if the German skippers present could give more information on their commercial midwater trawling since then for any species around Iceland.

Muschkelt (Germany): Cod was caught in good quantities by German trawlers with the midwater trawl off NW-Iceland in

autumn 1968. Depending upon distribution of the cod, as detailed by the echo sounder, both midwater and bottom trawls were used. Redfish was also caught at that time with large midwater trawls in considerable depth off SW-Iceland. At present there is no German midwater trawling around Iceland to my knowledge.

Libert (France): Midwater trawling of medium size French trawlers is mainly for herring on grounds with depths from 50 to 150 m. The midwater trawls used for instance on my trawler *Petit Moussaillon* (980 hp) are four panel nets with a circumference at the opening of 1,000 meshes (meshsize 200 mm stretched), with about 11 m opening height, or of 1200 meshes circumference (same meshsize) with an opening height of about 13 m.

In comparison with bottom trawls and semi-pelagic trawls, the advantages of the midwater trawl are as follows:

- No damage to spawning ground;
- The possibility of catching fish at any place and at any depth;
- A greater opening height enabling better catches;
- Easy fishing over rough ground where otherwise trawling would be impossible.

The disadvantages of using the midwater trawl are, in particular:

- The requirement of greater engine power in bad weather conditions to maintain the gear at a certain depth;
- A difficulty of operating in shallow water due to its large size.

French semi-pelagic trawling is mainly for herring, mackerel, whiting and cod. Predominantly two panel nets of 35 m headline and 42 m groundrope length with a circumference of 612 meshes (meshsize 160 mm stretched) are used.

The advantages of semi-pelagic trawling in comparison with bottom trawling and midwater trawling are:

- The opening height is greater than that of a bottom trawl;
- It enables trawling to be carried out on rough ground provided the groundrope is maintained at a distance of 1–2 m from the bottom through an adequate adjustment of the warp length;
- It can be used in very bad weather which would not ordinarily permit midwater trawling;
- It is the only highly productive trawl which can be used without difficulty at depths from 10 to 20 m, which is very important for herring trawling off British and French coasts.

Detection of pelagic fish by sonar needs a skilled operator. On the average, the first sonar contact is obtained at 1,000 to 1,200 m distance with fluctuation depending on the density of the school. On the other hand, echo traces are frequently obtained from a school of about 20 porpoises close to the surface at a distance of 500–600 m. Horizontal scanning also allows location and identification of wrecks or bottom obstructions (the acoustic signal received is proportional to the size of the wreck or obstruction). Differences between wrecks and fish schools are easily detectable by ear, both having distinctive sounds. Some difficulty may occur when a wreck is covered by a fish school. Detection of fish on the bottom is possible when the school is dense enough. In this case, good catches are obtained at depths down to 150 m (we have no personal experience at greater depths). Detection of depth variation from 20 to 30 m is possible according to the nature of the bottom. In fact, the main bottom irregularities can be avoided by use of sonar.

O'Connor (Ireland): There are two distinct midwater trawl herring fisheries off the Irish Coast. These are somewhat similar to that in UK as described by **Noel**. One is off the NW-Coast and the other is off the SE-Coast.

Fishing in the NW-area is usually from October to January and is carried on by wooden side trawlers of from 14 to 23 m length, 114 to 450 hp. This is a two-boat trawl fishery in 10 to 30 fm depth. Herring taken is predominantly spent. The gear is mainly of Swedish and Danish pattern with nets between 8 and 11 fm opening size. The bottom conditions vary from sand to solid rock and the predominant sea condition feature is ground swell. Fishing is carried on up to wind force 5 to 6 Beaufort and prevailing wind direction SW to NE.

In the SE area fishing is again from October to February and in depths from 7 to 20 fm on a bottom which varies from rough to solid rock. The vessels are similar to those used in the North West, but the gear is of German, Dutch and Danish type with nets of 8 to 10 fm opening size. Sea conditions are somewhat easier than in the North West and prevailing wind is again SW.

Vessels in both areas are well equipped with electronic aids including echo recorders and fishlupe. Sonar has been installed in a few craft but considerable problems were met and its use has been negligible.

Catches in both areas have marked 60 to 65 tons per tow but they naturally vary considerably in relation to the size, capacity and horsepower of the craft. Vessels which are not exactly matched in relation to these factors have successfully towed together, but the general tendency is towards equality in characteristics of the two boats.

Allers (Norway): With regard to midwater trawling in Norway two trends may be observed.

The larger sterntrawlers, some 5 or 6, have adopted the trawling procedure and trawl constructions practised in Germany. Herring and mainly cod are being caught.

During the last capelin (*Mallotus villosus*) season the total catch was approximately 1 million tons. The smaller purse seiners had converted quite successfully to sterntrawling for this species using a four panel, square one-boat midwater trawl. This conversion requires only the installation of removable gallows at the stern. The existing deck mounted power blocks and fish pumps are used for net handling and catch transfer from the codend. A netsonde has not been found necessary for this fishery and instead of two Süberkrüb otter boards, four wooden flat boards directly in front of the trawl are being used.

To give you an idea of the success of this operation I should like to mention that a 106 ft converted seiner with 180 tons capacity caught 2,500 tons of capelin in about 11 weeks. This result becomes more impressive when I explain that for three weeks the vessel was actively fishing for only 11 hours. This illustrates severe delivery problems at overworked fishmeal factories along the coast of Northern Norway.

Finally, I would mention that experimental fishing with this type of midwater trawl gear using the same net has been used for polar cod (*Boreogadus saida*). The first landing from a purse seiner of 600 tons of polar cod introduces a promising future for midwater trawling for this fish.

Dijkhuizen (FAO, Ghana): In Ghana there is one State and two private companies using approximately 20 large sterntrawlers. Echo sounders and sonars from Norway and Japan are used. The vessels are switching over to pelagic trawling, and fishing is mainly in the more profitable Dakar region, despite the longer sailing time.

Okonski (FAO, Argentina): In Argentina the research ship *Cruz-del-Sur* is investigating the feasibility of midwater trawling (and purse seining) for anchoveta. There are three types of midwater trawling conditions:

- typical midwater trawling in deeper water in the winter season
- near surface trawling over deep water
- near bottom trawling during spawning season in coastal waters

The most productive is the winter season which can be successfully exploited by local commercial vessels provided they are equipped with netsonde and sonar. Without this gear, only the coastal region can be partly utilized by local commercial boats. In this fishery only small size midwater trawls can be used because of shallow depth of 15 to 25 m. There is no basic difficulty to applying bigger nets during the winter season, but these must of course be related to the size and power of boats.

Robins (Australia): We have no midwater trawl fishery in Australia but hope to start one with our new research vessel. Our main trawling grounds are in the SE corner of Australia. We are also using Danish seining.

Echo sounders are common and most of this equipment comes from Europe or Japan. Sonar so far has hardly been used.

Cunningham (New Zealand): Bottom trawling in New Zealand is well developed down to 100 fm. So far only Japanese vessels are midwater trawling in deeper water. Echo sounders are standard equipment for trawling and pot fishing while sonar is in an early state of introduction and netsonde is not used at all.

Besancon (Netherlands): The coastal fishing fleet in Holland consists of about 500 vessels; about 90 per cent are fishing with the double beam trawl either for flatfish or shrimp. There is a strong tendency to increase the size of the ships to 25–30 m and the engine power to 600–1000 hp. The 10 per cent conventional bottom-trawlers will either have to change their operation or will go out of business due to low profits.

Christensen (Denmark): Shrimp trawling with otter trawls is important in Greenland. When looking for new grounds our echo sounders are not good enough. Are other types of echo sounders available for this work?

Dijkhuizen (FAO, Ghana): With a Furuno echo sounder with 200 kHz we have obtained good readings of shrimp in shallow water.

Kristjonsson (FAO): Good echo traces of shrimp may be obtained under favourable conditions, with normal echo sounders. Strangely enough there is no special shrimp echo sounder on the market. In spite of the prospective market of about 10,000 shrimp trawlers in the world there is no special shrimp echo sounder available .There should be no technical problems with the present knowledge to develop a suitable model for these small targets and I would therefore like to repeat my request to the industry to take this matter up seriously.

Nomura (Japan): The Japanese high-opening four and six panel trawls are used in single and two-boat operation for fish and also for shrimp. The opening height may reach 20 m.

Hamlin (USA): In New England one shrimp fisherman is experimenting with a 48 ft beam trawl on a 54 ft boat. He is getting the same shrimp catches with a smaller crew and about half the hp required for an equal-size otter trawl.

Fjeldsted (Iceland): It is difficult to construct suitable bottom trawls for the Icelandic fishing boats as they are very different in size. The effect of reducing towing resistance of trawling by means of bigger meshsize in the front part is remarkable. One Icelandic experiment to enable the increase in size of trawl by bigger meshsize offers promise.

Dickson (FAO, Poland): Recent trends regarding meshsizes in trawls are to make them bigger, but this does not work in all cases. One opposite example with reduction in meshsize is the Aberdeen trawl in which smaller meshes were introduced in the 1930's for the square and this was never changed back. This was for haddock and whiting fishing. Particularly where a trawl is small or rapidly tapered it is often necessary to carry the smaller meshes farther forward towards the mouth of the trawl.

Klima (USA): (In reply to question from Craig (UK)). There are no electrical fish trawls being used in the US, but there are one or two electrical shrimp trawls being used by Americans in the Gulf of Mexico.

FUTURE TRENDS AND POSSIBILITIES

Crewe (UK) Rapporteur: Of the wide scope of this subject six main topics are taken to be covered: Aimed trawling; net design; operation of several trawls alternatively so as to reduce non-productive time or to allow for rather sudden changes in fishing conditions; use of shipboard computers including automation of various parts of the trawling cycle; use of various other electronic aids; application of mathematical techniques and calculations. Nearly all these topics are considered by **von Brandt** and I shall use his remarks on future trends to provide a thread on which reference to the other contributions can be strung. Aimed trawling now covers all instrumental computer-assisted interceptions of net and fish both on or off the sea bed and when suitably qualified, **von Brandt's** future trends, which were mainly concerned with midwater trawling, can in general be taken to apply to this wider context also. He makes the point that aimed midwater trawling is continually being improved by further development in the design and operation of the hydro-acoustic equipment and by increasing gear size, but that the latter requires increased power also. **Maucorps** and **Portier** give estimates of areas exploited by modern bottom, semi-pelagic and pelagic trawls respectively and make a theoretical estimation of surface areas scanned by a sonar as compared with an echo sounder. Unfortunately such estimates do not give precise indications of the increase in vessel catching ability brought about by recent developments in equipment and techniques. It is concluded in this paper that estimation of increased catching ability is difficult due to the depletion of stocks resulting from their over-exploitation. **von Brandt** refers to this aspect also to the effect that decreasing stocks make necessary increasingly precise methods of interception that demand more observation and more knowledge of fish behaviour. Turning to detailed net design trends **Miyazaki** *et al.* investigate the comparative efficiency of nylon monofilament and polyethylene multifilament netting for small otter trawls. They conclude that because of its doubled efficiency for semi-pelagic fish and its equal efficiency as compared with a whole polyethylene trawl for demersal fish, the use of nylon monofilament netting in the upper parts of a small trawl can be recommended for commercial operation. The comparative results are attributed to the lower visibility of the transparent monofilament nylon. However, in line with the findings of **Maucorps** and **Portier** I would suggest that the

assumption that towing speed × net mouth height × net mouth spread and towing speed × net mouth spread alone are not good measures of trawl catching efficiency and should be treated with caution. There is a good deal of comparative fishing experience which did not show any such simple geometrical relationship. **Hamuro** gives design criteria for a midwater type purse seine based on model tests and proper calculations. Turning to the next topic **von Brandt** suggests that changing trawls must be made easier and quicker and mentions studies on the matter in the USSR, Poland and the Federal Republic of Germany. **Traubenberg** of the USSR considers an equation for the number of trawling cycles that can be achieved in a day and proposes that the conventional multipurpose trawl winch should be replaced by a set of single purpose winches so that the otter boards can remain attached to the warps during gear changes. For example two sets of bridle winches can be so located on the working deck that one trawl can be lifted along the ramp while the other is ready for shooting. In this way the total time for shooting and hauling a trawl, excluding the warps can be almost halved. If the winches are operated by remote control from a central panel only one winch operator who might also be the deck navigator or helmsman is required. I would just add that operation of trawls in sequence can allow efficient changes between such opposed pairs of conditions as pelagic and demersal fishing, high and low headline conditions, rough ground and good ground conditions, daytime and night time fishing and more than two gears might frequently be sequenced in some cases. With regard to computers and automation **von Brandt** refers to the proposals from the USSR to feed fish echoes from sonar and sounders directly into a shipboard computer that calculates how interception can be achieved. In an automated system the computer directly instructs the steering gear, main engine and winches on procedures for bringing the gear to the fish. **Birckoff** made proposals for automatic shooting and hauling in 1966. Reduction of manpower by computer-controlled automation is a general trend in industry today and is well suited for one-boat midwater trawling using large stern trawlers. **Hamuro** gives proposals for the automation of fishing with otter trawls, Danish seines, midwater trawls and purse seines in some detail. Automatic regulation of the headline height of bottom trawls and aiming of midwater and bottom trawls are considered, so are adjustments of seine nets during setting and hauling. Simple example results of the paper by **Crewe** *et al.* are of some relevance. This paper gives estimated ship tracks or paths required to obtain interception of trawl and fish on the bottom or in plan form but not depth off the bottom. Depth interception is no doubt best achieved by use of netsonde techniques. Turning to other electronic aids **Drever** considers automation by coupling echo sounder information to automatic gyro-controlled steering systems, so that a fixed depth can be followed in contour fishing. Decca Navigator might be used to control a vessel's course on a selected Decca lane and a system could perhaps be devised to repeat automatically a tow previously recorded by the track plotter. **Drever** considers also that it would be of tremendous benefit if telemetry could be used to provide direct relevant information on gear performance measurements such as otter board spread, headline height and possible damage. These matters are being actively pursued in Britain, Japan and elsewhere. Possibly, direct wire links might be better for this purpose than wireless telemetry in view of some of the discussions earlier today. The above subjects are in their infancy and **Drever** considers the development attractive provided the cost in established use is not likely to be prohibitive. Both **Drever** and **Hearn** are concerned with fish counters. **Drever** considers that an accurate automatic device giving displays in terms of catch rate over a period and total catch would assist in a maximum exploitation of the ground and prevent unnecessary hauling. The White Fish Authority Industrial Development Unit fish counter presented by **Hearn** has been discussed at fair length now in this Conference. I would only add here that this fish counter is one example of data processing in which it is found that a deterministic or simple algebraic relationship between counts and catches should not be attempted, but that instead a technique of a statistical type gives better results than a trawler officer of average skill can provide and is also of value to top class captains. Mathematical techniques and calculations are becoming more essential with the arrival of shipboard computers and proposals for automated systems. This type of mathematics is also required both in fully rationalized gear design and development procedures and in the production of computer controlled simulators for training trawler officers. The latter type of training is being considered for use in Britain, Iceland and Norway. The two relevant mathematical papers or papers with considerable mathematical content are by **Freedman** on the method of achieving optimum trawling operation and **Chaplin, Dickson** and myself on results of some basic calculations of vessel and gear tracks and on fish interception and aimed trawling. **Freedman** proposes a systematic procedure for obtaining an increase of up to 50 per cent in trawler operational efficiency merely by modernizing the gear so as to achieve an optimum relationship between the trawl, the ship, trawling techniques and fish behaviour. This requires among other things the trawl to be designed by calculations of the features of its main components and is achieved by the combination of calculation, model testing and full scale trials. This procedure is in fact generally similar to the one which I and the organization which I have been associated with since 1959 have applied. May I just comment that over the 11 years during which I worked on this topic it has been found necessary continually to increase the complexity of the mathematical models. Simple models don't work except in very few cases. This is often due to the scattered nature of the data that they are being compared with. Much better data would help. For example **Carrother's** recent Canadian tests where the speed of the net was measured directly in comparison with the drag have shown much better comparisons with simple theory than we were able to obtain in the past. Returning to **Freedman's** paper, I wonder whether the situation with regard to optimum trawling speed for a certain fish species really is as simple as his Fig 2 suggests. His calculations are concerned with the choice of linear dimensions for the net and with the choice of ropes and wires to provide adequate strength and also of course with calculations on otter boards, lifters etc. Relationships between model and full scale conditions are also discussed. The paper of which I am co-author, gives the results of mathematical calculations, but does not include the underlying theory. It is claimed that by this work it has been established that the track of bottom and midwater trawls appropriate to any given trawler track can be obtained by analytical methods suitable for programming in a computer. Segments of different track types can be combined and up-dating interception procedures can be used in which there is continuous monitoring of the position of the target relative to the trawler. Interception and sea bed track following techniques can be made much more precise if the relative position of the trawl gear from the trawler is instrumented. Finally it must be warned that attention has to be paid to gear collapse and vessel manoeuvre limitations.

Christensen (Denmark): Due to bad trawling conditions in Greenland and resulting gear damage we have been looking at the possibility of having two trawl tracks on the trawl deck, one alongside the other. In this way while one trawl is fishing the other can be repaired. Another possibility is to have a midwater trawl or a semi-pelagic trawl on one track and a bottom trawl on the other. We have also considered a net

drum mounted above the deck for stowing and handling a midwater trawl.

Hamlin (USA): A 100 ft sterntrawler in New Bedford has a net drum construction such that two nets are stored alongside each other.

McNeely (USA): The practice of using two drums is common in the Pacific North West of the USA. With this design, a low opening trawl can be stored on one side and a high opening one on the other. These drums are mounted either alongside each other or one above the other.

Jakobsson (Iceland): On the *Arni Fridriksson* our small research stern trawler (135 ft) we have mounted a power block above the middle of the trawl deck in front of the ramp and this makes the handling of large midwater trawls very easy and far superior to the stropping method. The power block needs less room than a net drum.

Christensen (Denmark): It is also important to protect the the crew particularly when fishing in arctic water. Gear repairs should be done in sheltered and heated rooms.

McNeely (USA): In my paper it is proposed to have a triple towing point on the vessel. From the Gulf of Mexico shrimp trawlers we know that two small trawls catch more than one large trawl and we have towed two shrimp trawls simultaneously for comparison purposes. This was just an experiment but I think it will have commercial implications. I think a good commercial system will be possible towing two trawls alongside each other without having to use beams.

di Mento (Italy): Italian fishermen used to trawl with four beam trawls at the same time.

Ben-Yami (Israel): A catamaran trawler *Experiment* has been recently tested by the USSR technicians under actual fishing conditions with, reportedly, remarkably good results. This vessel is using the alternate trawls method.

Freedman (USSR): The decks of the newer USSR sterntrawlers are divided and one trawl is handled on each side.

Results with the catamaran design have been successful and we want to develop this further.

Hjul (UK): A paper on the Soviet catamaran trawler *Experiment* was given by **Kadilnikov** at the Conference on Automation and Mechanization in February this year.

Frimannsson (Iceland): I wonder whether the price of a trawler catamaran may not be almost double that of a single hull trawler of comparative size. If two single hull trawlers were bought for this money they could operate the "two ramps" simultaneously even on different grounds.

Ben-Yami (Israel): In this experimental prototype probably economic aspects were not then considered.

The two main advantages of this catamaran are alternate operation of two trawls which saves time and the ability of the vessel to operate in much worse weather than single hull trawlers of the size of one hull. These may compensate, to some extent, for the obviously higher price of the catamaran design.

Heinson (Germany): The catamaran has good seakeeping qualities but cannot carry as much fish as the single hull vessel. The price would probably be about 1.7 times that of a single hull vessel.

Freedman (USSR): I think that the mathematical approach outlined by **Crewe** *et al.* is in the right direction. Similar work is also being done in the USSR.

Blaxter (UK): Regarding the interception techniques described by **Crewe** *et al.* the problem is that interception is slow but reaction of the fish is rapid. In order to speed up the updating, the environmental parameters and characteristics of fish behaviour as well as interrelations between the two should probably be included in the computer program.

Dickson (FAO, Poland): In strong cross winds and tides it is difficult to steer sterntrawlers in a chosen direction of tow. The new Polish research ship will be instrumented to measure the various forces and velocities involved. There is little time to make the quite complicated calculations required for the desired course and a computor system is no doubt necessary.

Muschkelt (Germany): I think we trawler skippers need as much information as possible on our gear. We found for example by netsonde that the bottom trawl almost never follows the same contour of the seabed as the trawler, i.e. the trawl is not in the same depth as the trawler and fish traces picked up by the ship's sounder are missed. Consequently a netsonde (sounding upwards) is needed for efficient contour trawling and this feature would have to be incorporated in a future automation system. We are already operating in this way.

Laevastu (USA): Obviously special purpose computers and display units might be used on board fishing vessels to assist in various communication display, decision making and control problems. However, general purpose medium size and large computers belong on shore. These are too sensitive to adverse environmental conditions, nearly impossible to maintain at sea and are also too expensive.

Kristjonsson (FAO): It is well known that American military and other planes are governed by operational computers which are probably, by now, commercial items. They are very compact, the size of the main unit being in the order of a cubic foot and costing something like $30,000. Such devices could receive information and translate it into action. They could also be coupled to memory banks, precision displays and what have you, depending on the money available for hardware. Does anybody know if such an operational computer has ever been put into a vessel?

Crewe (UK) Rapporteur: The American hydrofoil boat development of Boeing for instance includes an operational computer for controlling the auto stabilizing hydrofoil system. This costs about $30,000.

Stevenson (USA): There are many applications of specialized readout instruments on board fishing vessels. However, with the anticipated volume of information required for strategic and tactical fishing operations the computer requirements preclude location aboard vessels. The large computer requirements must be located on shore with terminal equipment to receive the data and return the evaluated information to the fishing vessels.

Relay communications with satellites from centralized land based computers will soon be a reality. For example, a research ship operating in the Gulf of Guinea had its oceanographic data transmitted via satellites to the United States National Oceanographic Data Center, Washington, D.C. Within 20 minutes all the data previously available for the area under research were printed out aboard the ship with the new data already incorporated.

Drever (UK): The idea of a computer aboard my trawler alarms me.

PART IV

FISHING IN THE FUTURE

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The Automated Fishing Platform

E. F. Klima

La plateforme de pêche automatique

Les étapes nécessaires à l'aménagement d'une plateforme de pêche automatique sont décrites brièvement. L'unité de pêche est basée sur différents modèles de comportement et de réponses à des stimuli, sur lesquels des recherches ont été faites par la Base de pêche exploratoire et de recherche sur les engins du Bureau des Pêches Commerciales, à Pascagoula (Mississippi). Le système nécessite l'attraction de poissons en bancs de petites dimensions et/ou peu concentrés par des structures submergées d'agrégation, le guidage de ces poissons par des stimuli lumineux convenables à partir de ces structures vers un emplacement central où une excitation électrique les concentre suffisamment pour permettre leur pompage sur une plateforme flottante où peuvent aussi être aménageés des installations pour le traitement.

La plataforma automática de pesca

Se describen brevemente los pasos que se están dando para la preparación de una plataforma automática de pesca. El instrumento se basa en las respuestas de los peces a determinados estímulos y en varios esquemas de comportamiento, que han sido estudiados en la Base de Pesca Exploratoria e Investigaciones sobre Artes de Pesca que la Oficina de Pesca Comercial tiene en Pascagoula, Mississippi. Se atrae a los peces, reunidos en pequeños cardúmenes o aislados, mediante dispositivos agrupadores sumergidos, y luego se les guía con estímulos luminosos adecuados, hacia un punto central, donde se les concentra mediante estímulos eléctricos y desde donde son aspirados, con bombas, a bordo de una plataforma flotante, que puede contar también con instalaciones para la elaboración del pescado.

ESTIMATED potential yields of fishery resources indicate that there is room for expansion of both United States and world fisheries. The annual potential yield of marine fish in seas near the United States is estimated at about 22 million tons compared with present production of only 2.3 million tons. Current fish production in the Gulf of Mexico is about 0.7 million tons compared with a potential yield estimated at roughly 16.5 million tons (Bullis and Carpenter, 1968). The coastal pelagic resources of the Gulf of Mexico could probably be expanded ninefold to about 5.6 million tons.

The major contributor to Gulf fish production has been the menhaden (*Brevoortia patronus*) and there are indications that its landings have reached or even surpassed the level of sustainable yield (Henry, 1966). This species is probably only the third most abundant coastal clupeid in the region. The most abundant clupeid stock in the Gulf is assumed to be anchovy, the second is thread herring. In addition, there are at least six other potentially harvestable species which school along the coast of the Gulf of Mexico. Commercial attempts to harvest these unexploited resources have been spasmodic and without any appreciable success. This has been due primarily to lack of knowledge on how to successfully catch these fast-swimming fishes with conventional gear (Butler, 1961).

Within the next 15 years, there will likely be an increase in fishing costs of about 80 per cent but the increases in fish prices during the same period will perhaps be only about 19 per cent (Norton, 1968). Thus, effective utilization of the Gulf's biological potential requires highly efficient harvesting systems. To achieve this the Bureau's Harvesting Programme at Pascagoula aims at developing a unique system which will allow profitable exploitation. A mobile-automated fishing platform, capable of attracting, controlling, and harvesting these stocks, should meet the objective. This platform will utilize submerged structures, lights, electric fields, and pumps (fig 1).

Light attraction

Lights have been used for many years to concentrate fish for commercial exploitation. In recent years saury in the Sea of Okhotsk and sprat ("kilka") in the Caspian Sea have been harvested with lights, fish pumps and nets.

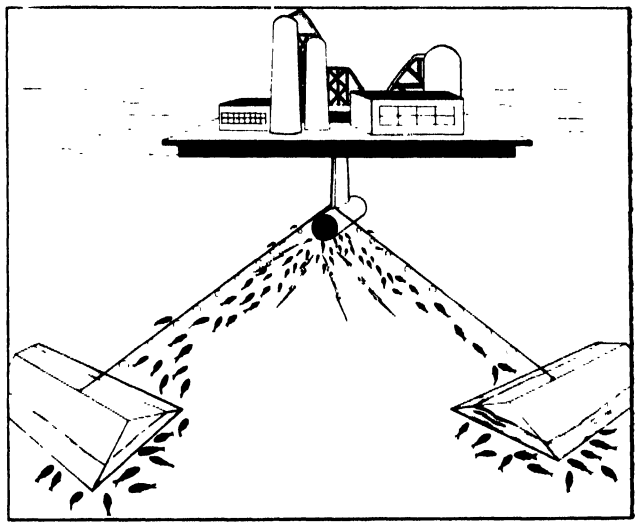

Fig 1. Automated fishing platform showing fish attracted to submerged structures and sequentially activated lights leading them to a central area where they are concentrated at a fish pump intake by an electric field

Observations in the Gulf of Mexico indicate that several of the coastal pelagic fishes are similarly positively phototactic.

As early as 1950, scientists from the Pascagoula Exploratory Fishing Base were using lights to attract fish. During the last decade, working in the Gulf of Mexico and Atlantic, they have used light to attract herring-like fishes for use as tuna bait. Surface lights hung over the side of the vessel were found to be satisfactory for congregating large quantities of anchovies and herring which were then caught in nets lifted up through the light beam. Submerged lights attached to a fish pump were used in 1966 in the Caribbean for sampling the pelagic fishes along the Lesser Antilles. Catch rates during a portion of this cruise reached a peak of 900 to 1,800 fish pumped per minute (fig 2).

Various species of herrings, anchovies, jacks, squids, and some mackerel-like fishes have been concentrated in large quantities around surface and sub-surface lights. Typical characteristics of these photo-positive animals is that they are generally of small size, form small

Fig 2. Light-attracted fish caught by fish pump in Caribbean

schools and are distributed along most of the coastal areas of the Gulf of Mexico and the Atlantic. These behaviour patterns prevent their economic harvesting with conventional equipment.

Research to evaluate means of harvesting these fish with existing commercial gear was done for many years. One technique investigated was to attract fish with lights and then purse seine around the lighted area. Sea trials with a 13,500 W surface light-bank and a 125 ft purse seine were conducted in the coastal waters of the north central Gulf with the Bureau's R/V *George M. Bowers* (fig 3). Purse seine sets averaged less than 1,000 lb; with anchovies, herring and sardines dominating the catches. However, these studies provided a basis for development of a new harvesting system—the automated fishing platform.

Current activity is to use experimental lights of known wave length and intensity as attraction stimuli. Results leave no doubt that coastal pelagic species can readily be attracted to selected areas by light. Figure 4 shows a typical echo recording of fish being concentrated throughout the night by a surface light.

Using underwater mercury vapour lights Wickham (MS) was able to concentrate and catch up to 3 tons per set of coastal pelagic fishes. He found that commercial purse seining around these lights was economically feasible but that catches were about one-third lower during full-moon periods than on the new moon. These initial steps have clearly shown that lights can attract fish but that they cannot sufficiently concentrate it for capture with pumps. Electricity should provide the means by which these fish could be adequately concentrated at the intake of a fish pump.

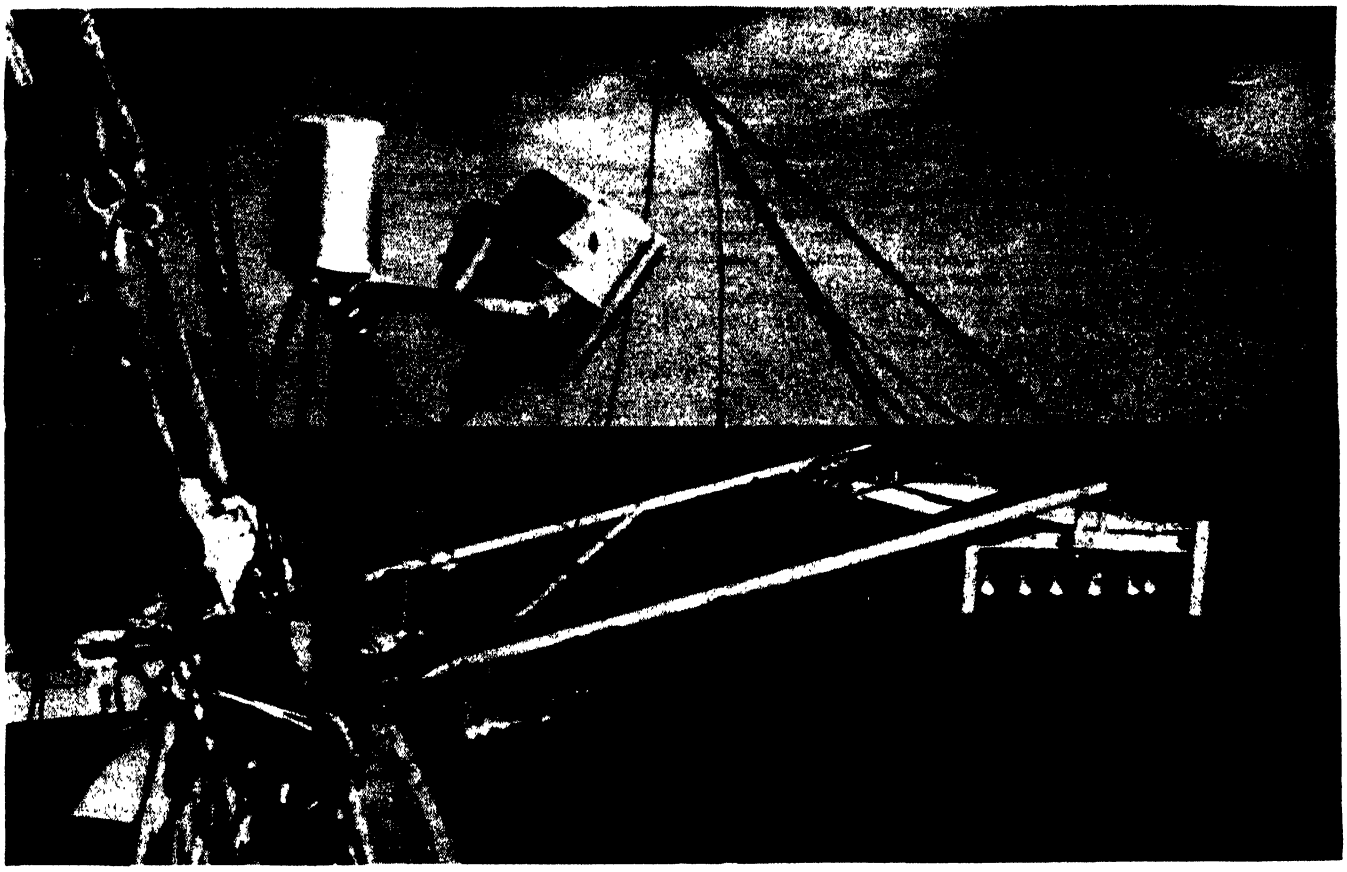

Fig 3. Light attraction equipment used in northern Gulf of Mexico with 13,500-W light bank and mercury vapour lamps

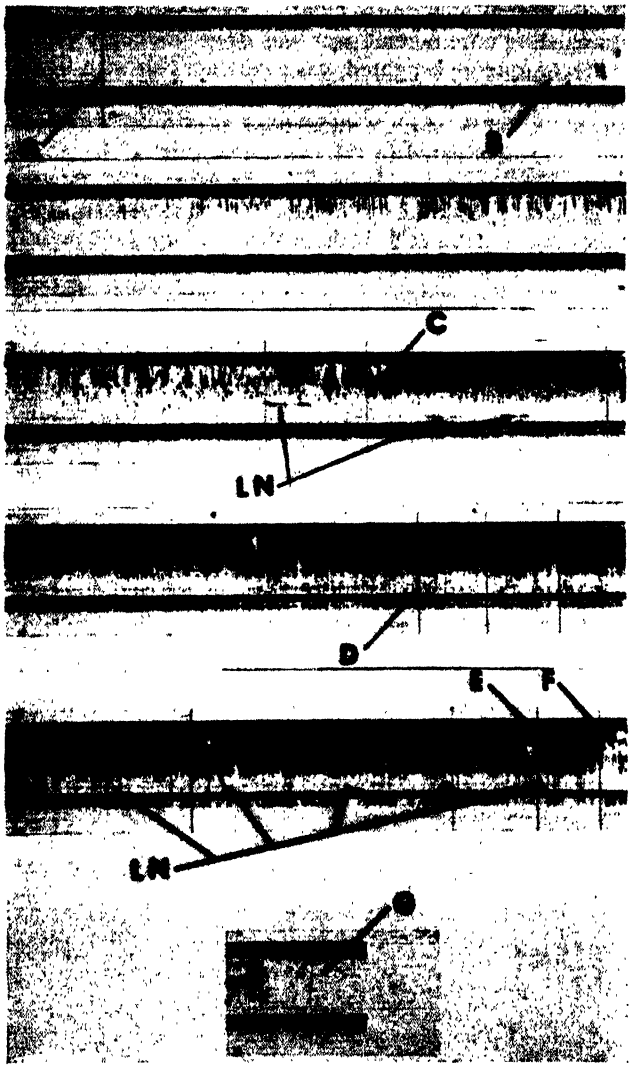

Fig 4. Echo recording made during light-attraction studies with an above-surface 1,000-W quartz-iodine lamp. Samples yielded Atlantic round herring, Etrumeus teres; *rough scad,* Trachurus lathami; *dusky anchovy,* Anchoa lyolepis; *bay anchovy,* A. mitchilli; *scaled sardine* Harengula pensacolae, *and small squid*
A = light turned on, 1900 h; B = nautical twilight, approximately 1945 h; C = 2200 h; D = 2300 h; E = 2400 h; F = light turned off, 0015 h; G = 0030 h; LN = trace of lift net

Electrical attraction

Various investigators have found that fish exposed to pulsed direct current showed three progressive reactions: fright, electrotaxis, and electronarcosis. Because of the high conductivity of sea water, pulsed direct current was found to be the most economical for use in the marine environment (Kreutzer, 1964). Until recent developments in electronics, it was not possible to produce pulse generators which could provide steep-gradient electric fields in sea water.

Laboratory studies now underway using modern electronic components clearly show that specific types of pulsed DC can effectively lead coastal pelagic fishes. In fact, electric fields with only slightly greater potential than 3.0 V per 10 cm can be used to induce a taxis in fish and thus lead them to specified areas. These studies are intended to evaluate and determine the optimum kind and amount of electricity for attracting and leading fishes as a basis to field-test the commercial harvesting system utilizing light, electricity, and pumps.

Aggregation

Observations by "Scuba" divers in the northern Gulf of Mexico indicate that small submerged rafts can attract and concentrate large amounts of coastal pelagic fishes (Klima and Wickham (MS)). The submerged structures (fig 5) which resembled small tents, attracted two types of fish. One group was designated as "jacks" and consisted of amberjack, *Seriola* sp.; blue runner, *Caranx crysos*; and rainbow runner, *Elagatis bipinnulatus.* The second group, designated as "baitfish", was more loosely associated with the structures and consisted of Spanish sardine, *Sardinella anchovia;* scaled sardine, *Harengula*

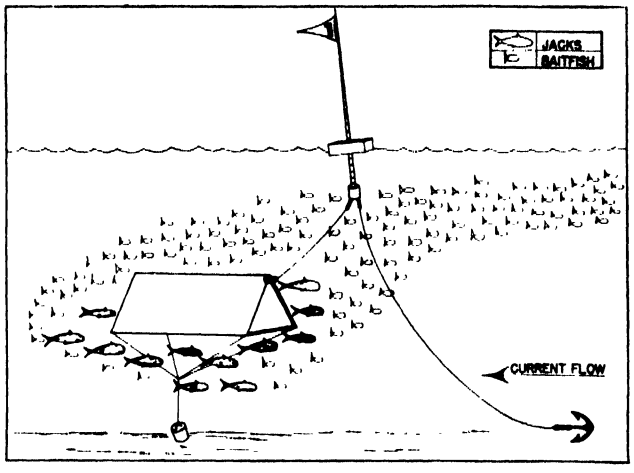

Fig 5. Position of baitfish and jacks in relation to submerged aggregation structure

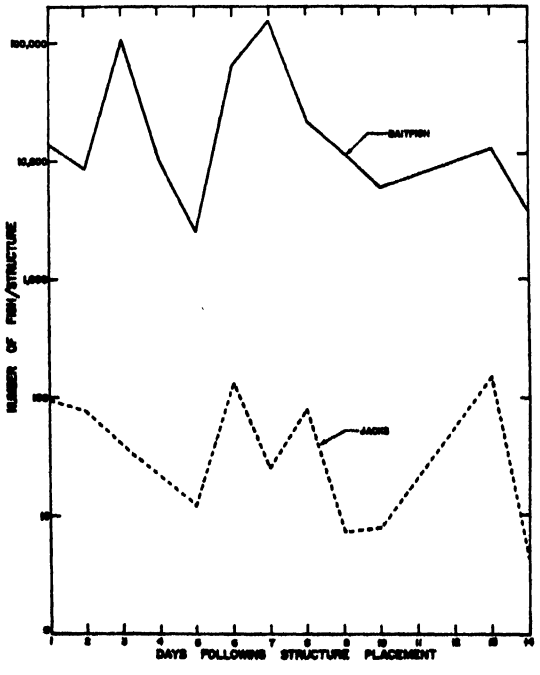

Fig 6. Estimate of the average number of baitfish and jacks collected per structure

pensacolae; and round scad, *Decapterus punctatus.* Daily observations showed that baitfish could be attracted in quantities exceeding 100,000 fish at each structure (fig 6). Klima and Wickham (MS) clearly showed that such structures could be utilized to attract coastal pelagic fishes during daylight hours.

The fishing platform

With the combined effect of submerged rafts, lights and electricity it is possible to visualize an automated fishing platform system. This might consist of a peripheral ring of rafts of several miles diameter which attract fish during daylight hours. After sunset the fish would be led by sequentially pulsed light to the centrally located platform (barge) where they could be further concentrated with an electrical field and pumped aboard. In addition large banks of submerged lights might be used to attract foraging fish which pass the fishing platform into the electric field.

The platform could be equipped to reduce the raw product to fish meal and also to extract the oil. Meal and oil can be held on the barge in piggy-bank trailers which can be picked up at weekly intervals by helicopters or mother ships. It is estimated that industrial fish could thereby be produced for less than the current rate.

Current status of development

The basic laboratory and field studies are well underway to determine the responses of coastal pelagic fish species to light, electricity and current velocities. These studies should provide the necessary information for the design of the prototype platform system. Field studies are being done to determine the optimum shape and size of the submerged rafts. A systems approach to the platform design and on-board equipment will be undertaken within the near future. The development of this new type of harvesting and processing sea-based system should allow profitable exploitation of presently unutilized fish stocks.

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Research on the Luring of Fish Schools by Underwater Sound

T. Hashimoto, Y. Maniwa

Recherches sur l'attraction des poissons au moyen d'un son émis sous l'eau

Des recherches ont été effectuées sur l'attraction des bancs de poissons par un son émis au moyen d'un équipement sonor sous-marin dans le but d'accroître l'efficacité des engins de pêche y compris la seine coulissante. En utilisant comme base les résultats obtenus sur la carpe, il a été possible d'attirer la sériole et le maquereau, et aussi de conduire des poissons dans un filet immobile.

Investigaciones sobre la atracción de cardumenes mediante sonido submarino

Se ha investigado el modo de atraer a los cardúmenes de peces mediante sonidos emitidos por equipo submarino, con objeto de aumentar el rendimiento de la pesca incluida la efectuada con redes de cerco. Sirviéndose de los resultados de los experimentos efectuados con carpas, como base, fue posible atraer peces-limón y jureles así dirigir a los peces hacia una red fija.

A DEVICE for gathering fish schools by using underwater acoustical equipment was conceived with the idea that if fish schools could be lured to a location and driven into a fish net by emitting an effective sound, fishing efficiency could be increased. Underwater acoustical equipment with a flat frequency response up to 7 kHz was designed for respective experiments. The results of experiments with carp were promising and were followed up by experiments on yellowtail (since 1963) and on mackerel (since 1966). Yellowtail and mackerel responded positively to the reproduction of feeding and swimming sounds of more than 17 dB and 22 dB

respectively (even in 13.5°C sea water). It was also possible to drive fish into a stationary net by emitting the sound of dolphins.

Underwater acoustic equipment

The underwater acoustic equipment consisted of an amplifier and an underwater sound projector. The transducer made of barium titanate was 190 mm in diameter and 123 mm high, and was securely enclosed in a rubber case.

The transmission frequency response characteristic of the underwater sound projector (fig 1) and the frequency response characteristic of the amplifier (fig 2) are complementary so that the general frequency response characteristic of the whole equipment is flat (fig 3).

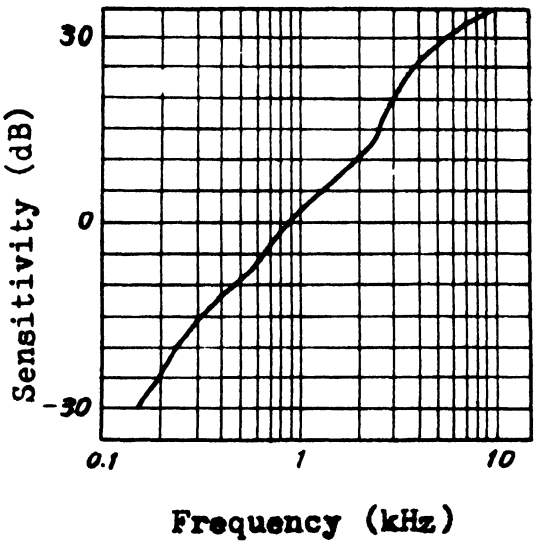

Fig 1. Frequency response characteristic of the underwater sound 0 dB: 1 μbar/1 V⁻¹

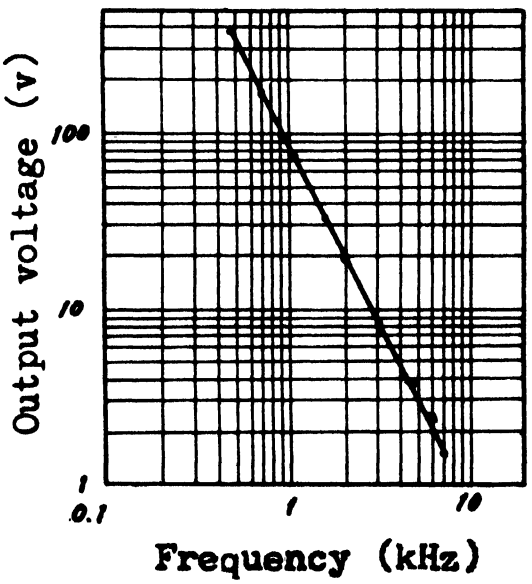

Fig 2. Frequency response characteristic of the amplifier

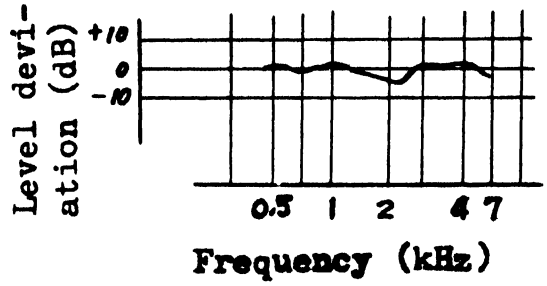

Fig 3. General frequency characteristic of the underwater acoustic equipment

Experiments on luring fish schools

In November 1963 bait eating and swimming sounds of yellowtail were first recorded off Odawara on magnetic tape by means of a hydrophone. The sound was produced by pouring anchovy into a fish culturing net and the recorded sound was immediately played back into the culturing net with approximately the same sound pressure. Young yellowtail responded to the sound by swimming up from the bottom to the surface towards the sound projector.

The sound pressure to which the young yellowtail responded was further investigated in a culturing net at Kushimoto, in February 1968. Fish responded to bait eating and swimming sounds emitted by the sound projector. With a sound pressure of more than 17 dB (re 1μ bar). From swimming counter-clockwise at a depth of 3 m they changed to a clockwise rotation and ascended 1 m. This is apparently the behaviour of fish when searching for bait.

Yellowtail were normally not active enough in water of 13.5°C to feed on silverside (baitfish) swimming nearby. They attempted, however, to feed during the sound emission.

Experiments on the luring of fish schools were made on the yellowtail fishing grounds in Wakayama in 1965. A fish finder was used in the experiments to observe the behaviour of fish schools. Before the emission of sound, fish schools swam at depths of 50–80 m, but when bait eating and swimming sounds of yellowtail were emitted they ascended towards the sound projector which was hung at a depth of 15 m (fig 4(a)). In another experiment

Fig 4. Echo traces of fish finder during sound emission. Yellowtail ascended toward the underwater sound projector. Top 1965, Bottom 1966

conducted in October 1966, the sound projector was hung at a depth of 10 m. It was shown by the echo traces of the fish finder that fish schools ascended towards the sound projector (fig 4(b)). Test catches of yellowtail at a depth of 10 m were successful during the emission of sound. Conversely, without sound emission, the fish did not ascend to the depth of 10 m even when bait was put in the water. This apparently shows that yellowtail responded to the sound.

A measurement of the sound level to which mackerel would respond was also made in a culturing net with swimming and bait eating sounds of this species. Before the sound emission, mackerel swam slowly clockwise at a depth of about 2 m in the net. In response to the sound pressure of about 22 dB, they ascended about 50 cm, increased their speed, and appeared to search for bait.

In 1967, experiments were performed at Zenisu which is a very good mackerel fishing ground. At this fishing ground, mackerel are normally gathered by fish lamps, but no lamp was used in this experiment. Swimming and bait eating sounds were emitted to the schools which were detected at depths of 40–80 m by a fish finder. The sound pressure was adjusted to be 22 dB at the depth of the school of fish. Ten minutes after the sound emission started, many fish gathered at depths between 17 and 40 m (fig 5). Fish dispersed after the sound emissions were stopped.

Such sound was successfully used also to lure fish schools which included mackerel and jack mackerel.

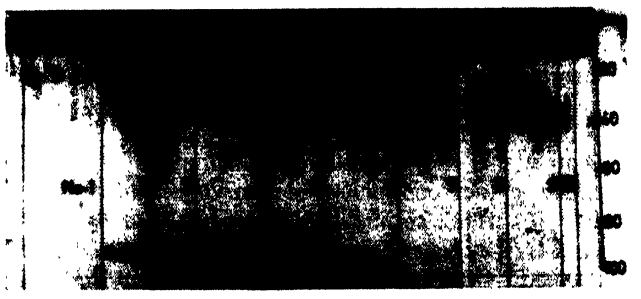

Fig. 5. Echo traces of fish finder during sound emission. Mackerel were gathered at the depths of 17 to 40 m

Experiments on driving away fish schools

Experiments using sound to drive away fish were made at the Odawara stationary net fishing ground in August 1964.

There had previously been a number of observations made on various kinds of fish schools being startled by dolphin sounds. The sound of Risso's dolphins was used in experiments on 26 and 27 August 1964 with the aim of driving fish into a stationary net. The sound was emitted through the sound projector from the opening of the net. Prior to this only young mackerel and young jack mackerel had been caught in the stationary net. However, 400 kg of barracuda and 800 kg of adult jack mackerel, plus an additional 800 kg of young mackerel, were caught on the morning of 27 August, the day after the Risso's dolphin sound had been applied. Similarly, 1200 kg of barracuda and adult jack mackerel, plus an additional 240 kg of young mackerel, were caught on the morning of 28 August after sound application. The catches after the experiments were again all small jack mackerel.

Conclusion

The underwater acoustic equipment was successful in luring yellowtail and mackerel. Furthermore, it was possible to drive jack mackerel and barracuda into a stationary net. Because of these results experiments to apply this method in practical fishing are being carried on.

Acknowledgement

Gratitude is extended to Dr. Suzuki, Assistant Professor of Tokyo University of Fisheries; to Mr. S. Nomura, Director of Kanagawa Prefectural Fisheries Research Institute; to Mr. H. Sakazume of Wakayama Prefectural Fisheries Research Institute and to Mr. F. Watanabe of Chiba Prefectural Fisheries Research Institute.

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Studies on Automation of Fishing with Otter Trawls, Danish Seines, Midwater Trawls and Purse Seines

C. Hamuro

Etudes sur l'automatisation de la pêche au chalut, à la seine danoise, au chalut pelagique et a la seine coulissante; criteres pour le dessin d'une seine coulissante pour la pêche entre deux eaux

Le manque de main d'oeuvre pour les navires de pêche devient de plus en plus important au Japon. Pour pallier à cette situation, des études ont été effectuées sur les méthodes et les moyens d'automatisation de la plupart des opérations de pêche. Des mécanismes contrôles par des dispositifs électroniques ou mécaniques ont été conçus qui pourraient tenir compte, en faisant automatiquement les corrections nécessaires, des variables sur lesquelles le patron de pêche et l'équipage devraient normalement prendre des décisions. L'intégration automatique du régime du moteur, du pas de l'hélice et des détecteurs de poisson est proposée pour ajuster l'ouverture verticale des chaluts de fond. L'intégration des données du sonar, de l'appareil à gouverner, du régime du moteur et des commandes du treuil est suggérée pour (1) le contrôle des chaluts de fond et pélagique et (2) l'obtention des corrections nécessaires pendant la mise à l'eau et le virage du filet dans la pêche à la seine danoise à la seine coulissante. Des essais de maquettes de seines coulissantes ont montré les possibilités d'utilisation de filets immergés de taille normale pour la pêche entre deux eaux jusqu'à une profondeur de 300 mètres. Il est nécessaire toutefois de déterminer les longueurs appropriées des cordages de soutien fixés aux flotteurs de surface de très grande dimension, ainsi que la relation entre la flottabilité et les poids de lestage.

Estudios sobre la automatización de la pesca con redes de arrastre de puertas, redes de cerco danesas para pescar entre dos aguas y redes de cerco de jareta; criterios para diseñar un tipo de red de cerco de jareta para pescar entre dos aguas

La escasez de mano de obra en los barcos de pesca se está haciendo cada vez más aguda en Japón. Para afrontar este problema se están efectuando estudios acerca de los modos y los medios para automatizar casi todas las operaciones pesqueras. Se han diseñado mecanismos controlados por medio de aparatos electrónicos o mecánicos que tendrían en cuenta las variables en relación con las cuales el patrón y la tripulación adoptarían normalmente sus decisiones; además de tener en consideración dichas variables, los mecanismos efectuarían automáticamente los reajustes necesarios. Para regular la abertura vertical de las redes de arrastre del fondo se propone la integración automática de la velocidad del motor, del paso de la hélice y de los localizadores de peces. Se sugiere la integración del sonar, mecanismo de gobierno, velocidad del motor y movimientos de la maquinilla para (1) dirigir las redes de pesca entre dos aguas y de fondo, y (2) efectuar reajustes durante el calado y el izado, cuando sea necesario, en la pesca con redes de cerco danesas y con redes de cerco de jareta. Los ensayos efectuados con redes modelo de cerco de jareta han demostrado la posibilidad de emplear redes de gran tamaño para pescar entre dos aguas a profundidades hasta de 300 metros. No obstante, es necesario hacer los cálculos adecuados de la longitud de las brazoladas que descienden desde los flotadores de gran superficie así como de la relación que existe entre la flotabilidad y el peso del lastre.

In recent years there has developed an increasing shortage in manpower for fishing crews and also an increase in the average age of fishermen. This has been caused by industrialization of coastal areas and cannot be reversed. Consequently, means of mechanizing and rationalizing various fishing methods and vessels are being studied.

Performance of fish finders has improved over past years. Many trawlers are now using telemetering instruments which provide several kinds of information. Controllable pitch propellers with remote control, remote controlled main engines and electric or hydraulic trawl winches are found on modern trawlers, but operation of instruments and gear still require trained fishermen. Automatic control of various fishing operations is attempted by linking together electronically the measuring instruments (e.g. fish finders, sonar, radar, gyro compass, net height telemeter, depth telemeter, tension meter, log, etc.) with the controllable pitch propeller, main engine, steering machinery, winches, etc.

The aims in the development of such automatic control systems are to improve fishing efficiency, to reduce necessary need for skill and experience of skippers and officers, to save manpower and to reduce the size of fishing gears.

Automatic net height control equipment for bottom trawling

In otter trawling, if the boat's course does not change while towing, the trawlnet ought to pass over the same ground over which the boat has passed. The trawlnet would then hit the fish school which was found with the ship's echo sounder, but if the net height (h) is lower than the height of the fish school (H), the fish school will not enter the net.

Aim of the net height control equipment is to cover the fish school completely and automatically. The net height (h) which should be adjusted to that of the fish school (H), is dependent on the towing speed which can be varied by changing the propeller pitch or the engine revolutions.

Figure 1 shows a schematic side view of adjusting the net height to the fish school height during towing, and fig 2 shows a block diagram of the automatic control equipment.

As is shown in fig 2, the net height is telemetered to the trawler and fed into the fish finder. Both records of the net height and the fish school height are recorded simultaneously on the recording paper of the fish finder.

After both data are converted to electrical voltages their difference is compared by the digital-analogue converter. If the net height (h) was lower than the fish school height (H) at normal towing speed, the towing speed is changed to increase the net height to $H+\alpha$ by adjusting the controllable pitch propeller or the revolutions of the main engine making due allowance for the distance between the fish school and net.

A magnetic tape delay circuit is used in the equipment so that no change is made until the net arrives at the fish. The relation between the trawlnet height and the towing speed and the relation between the towing speed of the trawler and the pitch of the propeller is as shown in

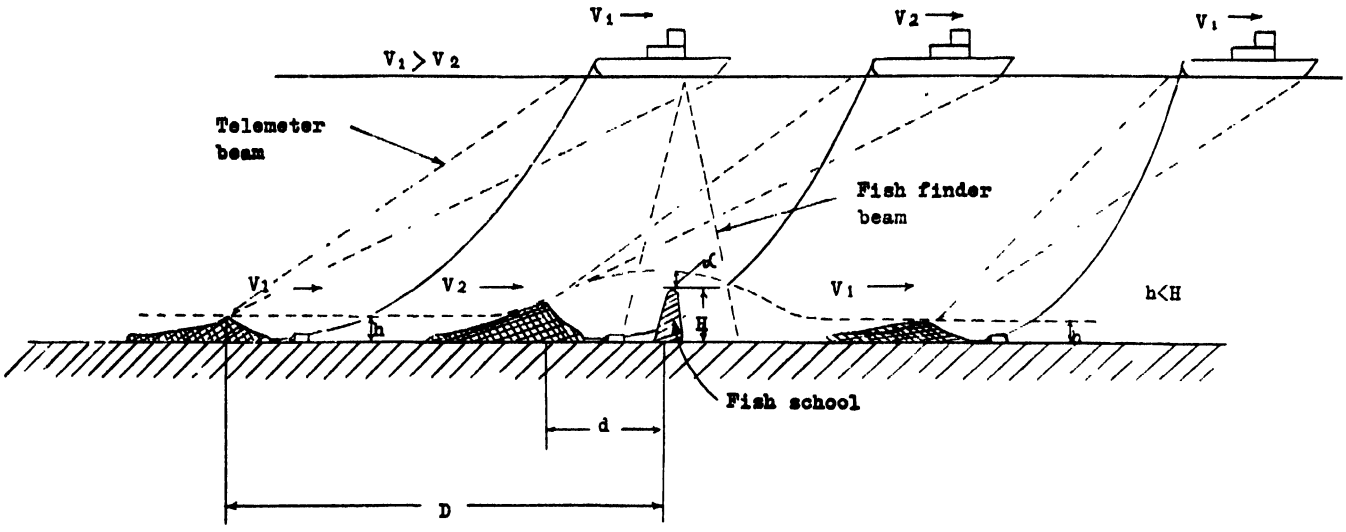

Fig 1. Schematic view of the automatic net height control system for bottom trawling

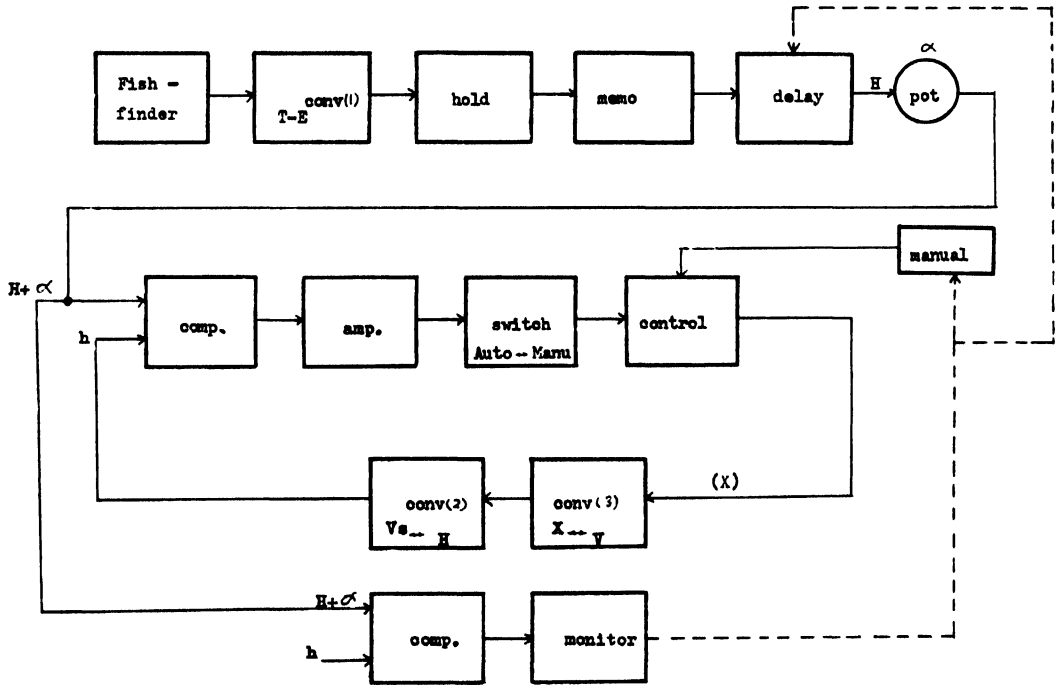

Fig 2. Block diagram of automatic net height control equipment for bottom trawling
X = control of controllable pitch propeller

figs 3 and 4. The parts Con 2 and Con 3 (fig 2) are constructed of the pin board type function generators and high speed comparator, and they automatically provide the new pitch angle needed for the new net height ($H+\alpha$).

One to five minutes after the trawlnet has passed the position of the fish school, the towing speed (V_2) is reset automatically to the normal towing speed (V_1) by changing the pitch or the main engine revolutions.

The lower limit of the towing speed must naturally be within the limits in which the net maintains its catching efficiency. A restriction is therefore present on the pin board. When the net and the otter boards are changed, the pins must be reset to the new conditions.

The following benefits are expected from this control system:

(a) If the fish school reaches higher than the net height the net would not be able to catch the entire fish school, thus the catching efficiency can be increased.

(b) It is not necessary any more to use a net large enough to cover the highest fish school in the usual way. Thus the economy can be improved by selecting smaller engines, smaller trawl gear and save fuel.

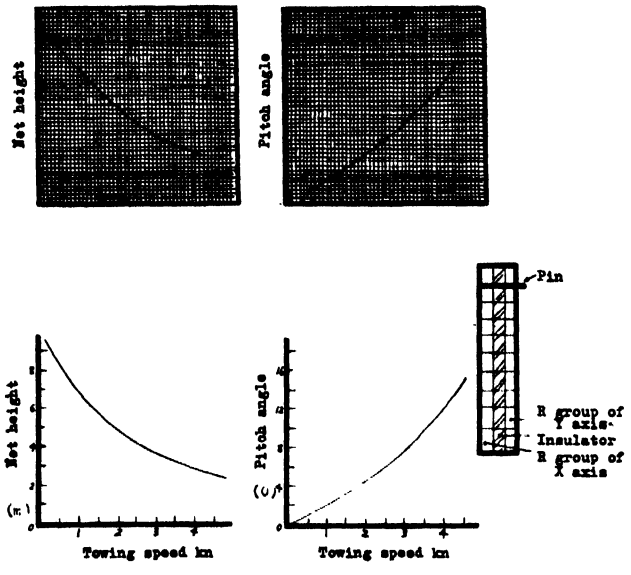

Fig 3. *Fig 4.*

Fig 3. Pin board type converter (above) and example for speed/net height relation (below)
Fig 4. Pin board type converter (above) and example for speed/propeller pitch relation (below)

(c) The skipper is relieved from controlling the fishing operations. The control equipment scientifically controls the towing speed more efficiently than the skipper could.

Automatic control (programming system) for Danish seining

As shown in fig 5, the warps of fibre rope and the net are set diamond shape. The net is towed with various pitch angles of the controllable pitch propeller.

After the net is towed for about 5 to 15 min the warps are hauled in by winches while towing is still going on. During this operation the skipper must continuously adjust the pitch angle of the propeller in accordance with the change of conditions of the warps at the stern.

Automatic control equipment consists of the following five parts:

Control panel
Measuring instruments for the warp angles
Stopper for the warp
Winches and reels
Controllable pitch propeller.

The warp angle is continuously measured at the stern and the measured data are transmitted to the control panel on the bridge.

The meter consists of two levers which are attached one to each warp and turn a potentiometer according to the warp speed.

Two kinds of stoppers are used for Danish seining. One is a hook which is mounted on the top of each bulwark on the inside of the ramp; the other is a controllable hoop stopper mounted in the same position. The fixed type stopper is shown in fig 6. A ring attached near the end of each warp is hooked to the stopper when all rope has been paid out.

Winches on Japanese Danish seiners employ a special sheave and a rope reel for each warp (fig 6). Hauling speed

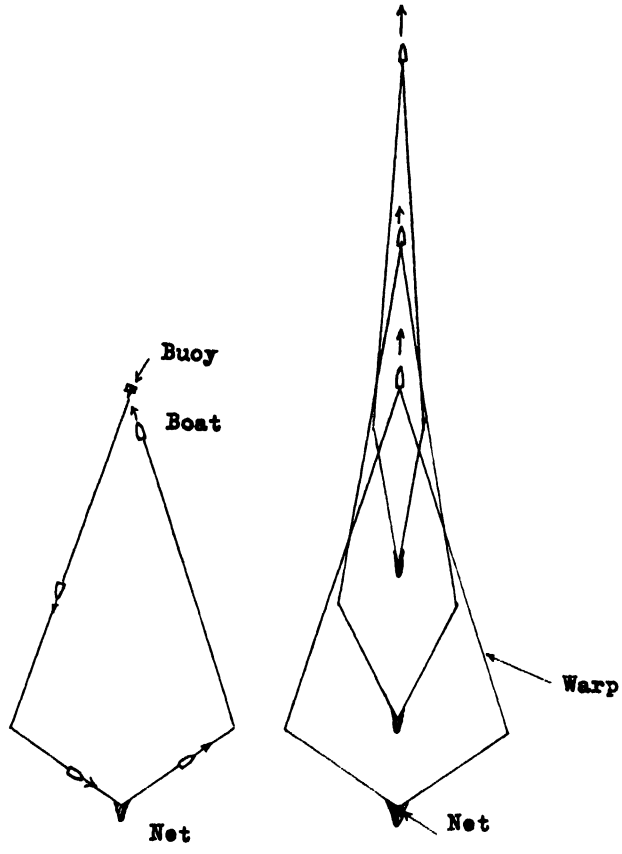

Fig 5. Schematic view of Danish seining operation (fly dragging)

of the warps changes automatically according to the diameter of the warp at a constant winch speed. Warps hauled by the winches are rolled onto reels located behind each winch. All equipment is hydraulically driven.

After the whole length of the warps has been paid out and the rings at the rope's end have been fastened to the hooks, the control dials in the control panel are adjusted to automatically perform the following:

1. Adjust the correct pitch angle of the propeller according to the desired angle of the warps at the stern
2. Control starting and stopping of winches and reels at a preset rope angle
3. Re-adjust the control settings according to the changing towing conditions.

Automatic control for midwater trawling

Automatic control equipment that accurately aims midwater trawlnets to intercept fish located by echo sounders was constructed to operate in conjunction with the echo sounder and depth telemetering system. The controllable pitch propeller, main engine and trawl winch are also integrated into the system (fig 7).

The equipment consists of the following four main parts:

(i) Telemetering net depth meter
(ii) Trawl winch
(iii) Vertical type fish finder echo sounder
(iv) Control unit.

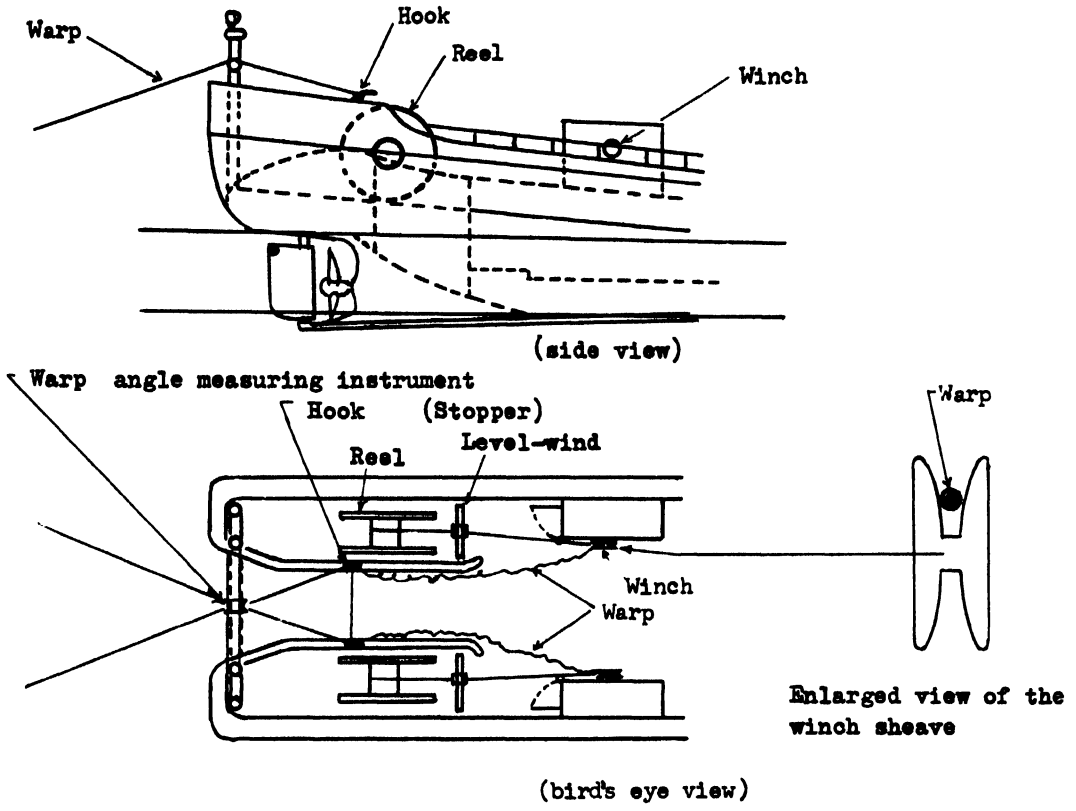

Fig 6. Position of warps at the stern of a Danish seine boat

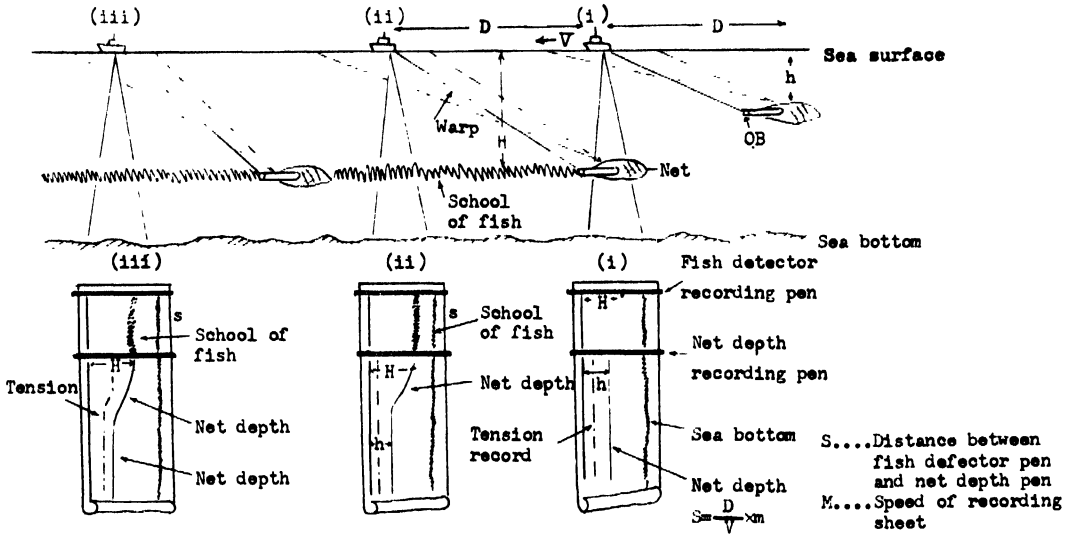

Fig 7. Scheme of automatic midwater trawling

The depth of the fish school and the depth of the mid-water trawl are both recorded on the paper of the fish finder simultaneously.

After setting the control unit to the depth of the fish school this unit orders the winch to haul or veer to bring the net to the correct depths. During this process, the depth of the net and the fish school are continuously compared by the digital-analogue converter in the control unit until they are equal and the trawl winch is ordered to stop (fig 7).

Future developments of automatic equipment for otter trawls and purse seines

This equipment is under study by the author, but is not completed yet. However, the object and the principle will be described for reference.

When a trawler aims for a fish school located by sonar, the trawlnet must be guided to that position. This is difficult for the skipper and automatic aiming equipment could therefore be useful.

The equipment would consist of the following parts:

(i) Sonar
(ii) Net depth telemeter
(iii) Gyro compass
(iv) Steering machine.

The intention is to automatically steer the net with this equipment towards a fish school even if this is not on the course of the trawler.

When the purse seine net is set out (either day or night), the position of the fish school and the shape of the purse seine must be known by the skipper, but he can see only the seine and cannot be sure of the position of the fish school. So, study is being made of a means to automatically control the setting of seines more effectively.

Equipment that may be used includes the following:

(i) Sonar
(ii) Radar
(iii) Gyro pilot
(iv) Remote control stopper for the end of the purse seine (on the floatline).

Studies on design of a midwater type purse seine

In Japan the depth of purse seines is being increased more and more to be able to fish mackerel which are located down to 200 to 300 m depth in winter season. If the size of a seine is increased vertically it must also be lengthened to obtain a good shape in the winter.

Consequently, the cost of the nets becomes very high and also the stability of the vessels is affected by the higher weight. Furthermore due to two or three different current layers within the increased depth ranges, the seine is often distorted and may also be torn.

The object of the midwater type purse seine is to avoid the increase in net size and thus also the related problems.

The outlay of the proposed midwater type purse seine would differ from the conventional seines mainly by additional vertical floatlines equipped with large size floats which are attached to the normal floatline at regular intervals (fig 8).

As regards the relation between buoyancy and weights the following conditions must be satisfied:

$$Fn+fm>W_1+W_2+R$$
$$fm>W_1+W_2+R$$

F_n Total buoyancy of the large surface floats

f_m Total buoyancy of the normal floatline which is to be sunk in the water

W_1 Total weight of the purse seine without the rings, the bridles and the leadline in water

W_2 Total weight of the rings, the bridles and the leadline in water

R Sinking power needed to sink the usual floatline with due consideration to the total fluid resistance of the purse seine in water.

During pursing and hauling, the weight of the rings, the leadline and the lower part of the net is gradually hauled aboard. Consequently, the relation of $f_m<W_1+W_2+R$ changes gradually to $f_m>W_1+R$, and the normal floatline comes to the surface with the net in good shape to keep the fish school which was caught at a greater depth.

Experiments with a 1:130 scale model (according to Tauti's rules) of such a midwater type purse seine confirmed that the desired performance and expected advantages could be obtained. It was further found that the sinking speed is considerably faster as compared to deep purse seines of conventional design.

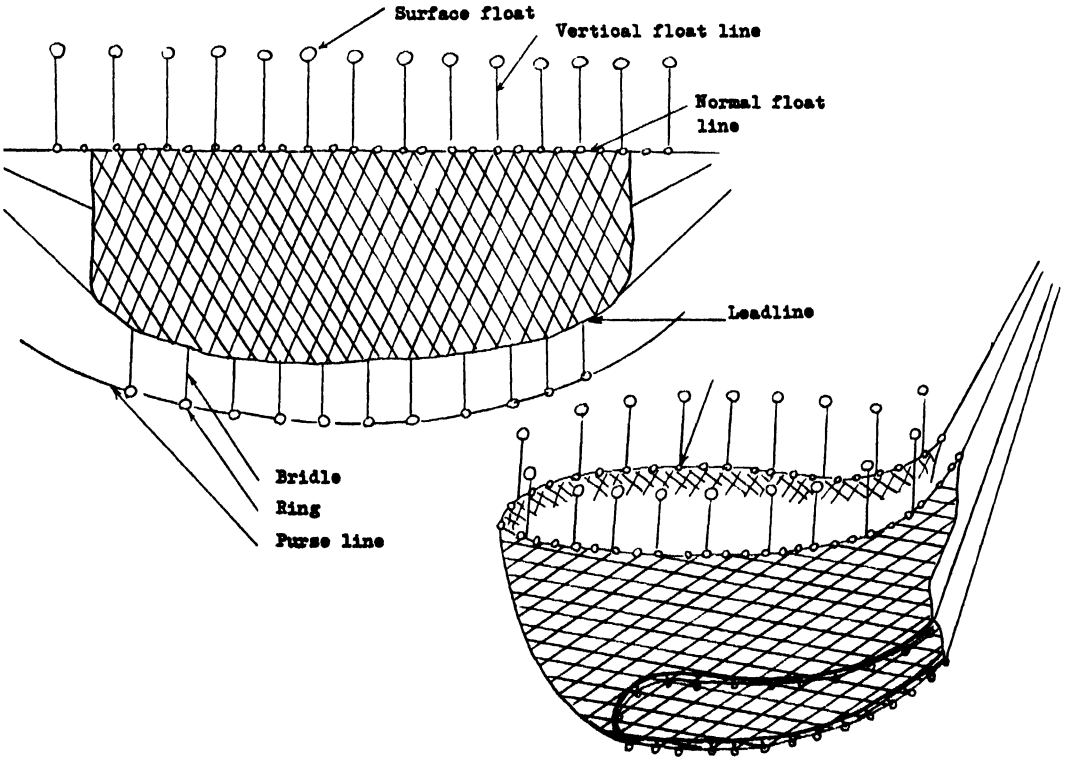

Fig 8. Scheme of midwater type purse seine net

The Future of Fisheries

N. J. Wilimovsky, D. L. Alverson

L'avenir des pêches

En plus des progrès techniques, les facteurs sociaux, économiques et ceux ayant trait à la gestion et aux aspects juridiques auront une influence sur les pêches de l'avenir. L'homme doit maintenir la productivité des océans, développer la gestion internationale en résolvant les problèmes de juridiction et développer les techniques pour l'utilisation maximum des ressources océaniques. La plupart des savants pensent que la production des espèces communes peut être quadruplée avec les techniques actuelles et qu'au delà, de nouveaux moyens doivent être trouvés pour récolter des formes trophiques inférieures. Le guidage des flottes de pêche utilisant des calculateurs électroniques à bord, la navigation par satellite, les instruments soniques perfectionnés, les lasers et la télévision sous-marine, couplés à l'information rétroactive coopérative des navires de pêche augmentera l'efficacité de pêche. Le dessin modulaire des navires améliorera les petits navires côtiers. Les études du comportement du poisson seront combinées plus efficacement à la technologie des engins. Les treuils à grande vitesse feront progresser l'emploi de trappes en eau profonde attachées à des lignes longues. Les protéines de poisson seront produites sous différents goûts, textures et couleurs.

El futuro de la pesca

Además de los adelantos técnicos, en la pesca del futuro ejercerán su influjo factores sociales, económicos, administrativos y jurídicos. El hombre tiene que mantener la productividad de los mares, crear una administración internacional mediante la solución de los problemas de jurisdicción y formular técnicas para aprovechar hasta el máximo los recursos de los océanos. Casi todos los científicos creen que la producción de las especies comunes puede cuadruplicarse con las técnicas existentes y que para exceder esa cantidad se tendrán que encontrar nuevos medios de recolectar las formas tróficas inferiores. Aumentará el rendimiento al guiar las flotas pesqueras empleando ordenadores a bordo, mejor equipo sónico de navegación con ayuda de los satélites artificiales, incluídos los lasers, y la televisión subacuática, junto con la transmisión cooperativa de información por los propios pesqueros. Las formas modulares de los barcos mejorará los costeros pequeños. Los estudios de las reacciones de los peces se combinarán más eficazmente con la tecnología de los equipos. Las maquinillas de gran velocidad permitirán emplear en aguas profundas andanas de nazas sujetas a una sola línea. A las proteínas del pescado se les darán diversas clases de texturas, colores y sabores.

A little over six years ago, Hilmar Kristjonsson, Chief Fishing Gear Section of FAO, asked us to prepare a paper on "Fishing in the Future" for the Second Fishing Gear Congress. Our efforts, made as a serious appraisal and published in "Modern Fishing Gear of the World 2" (Alverson and Wilimovsky, 1967), gave rise to a certain amount of merriment. The paper (taken with varying degrees of seriousness) has been much quoted or paraphrased, frequently prefixed with the word "fictional". Since that time, the art of technological forecasting has achieved some legitimacy, though it is still with some trepidation that we make our second venture into this new field.

In our past paper we attempted to forecast technological development that might be anticipated in fisheries during the ensuing three decades. In this paper though we reappraise some of our earlier comments on technology, we emphasize some social, economic, managerial and legal factors which will influence the character of fishing during the next decades. Primary among these we ask whether or not man will be able to:

1. Maintain productivity of the oceans' biological systems; that is, prevent pollution or other misuse which may impair its reproduction or contaminate its food products

(2) Institute national and international management and develop schemes which will optimize yields or opportunities available in the ocean

3. Resolve jurisdictional and institutional problems

4. Develop technological components which will allow utilization of a large part of the existing biological potential.

PREMISE

It is apparent that mankind's piecemeal provincial approach to environmental problems and use of the oceans' living resources has led to an unacceptable state of affairs. The need to formulate broad national and international policies seems the only practical approach to resolving existing problems. The entire field of policy formulation is developing rapidly; for example, see national reviews published by the Organization for Economic Cooperation and Development. Such studies make apparent the danger of taking too limited or parochial a view. Only by evaluating the myriad interactions between policies and potential technological developments can we develop some concept of what contribution fisheries may make in future to mankind. Few individuals will concede that we can predict the future, but there is a growing realization that man's technology does allow him to guide his future in many areas. Indeed, an entire spectrum of analytical procedures is available (Jantsch, 1967), each with its own formalized jargon. (It is interesting to note that our earlier description of "Fishing in the Future" now qualifies as a "scenario"). Some of these techniques have achieved considerable sophistication (see, for example, journals such as *Futurist; The Journal of Forecasting and Planning; Analysen und Prognosen, Uber die Welt von Morgen;* and *Long Range Planning*). It should be emphasized that prophecy and forecasting are not synonymous.

Identifying key questions and likely consequences of potential policies will be fundamental to rational exploitation of the aquatic environment as they relate to man's total needs and wishes. Individual components appear to break up into the following broad headings: the need, the resource, its harvest, the product use and finally, the overall management of the resource in terms of economic, legal, social, and educational constraints.

It is apparent, if we are evaluating the future of global fisheries that such a project cannot be unilateral and must take into account factors outside the realm of fisheries. The process is one of continual refinement or feedback in defining the key questions and inter-relationships. In the

hopes of initiating such a chain reaction, we offer the following speculations on critical areas in fisheries, some key questions and problems of interactions.

The need

It is evident a solution to the world's food problem must include a plan to bring population under control, and should this be possible, we know the contribution of the sea will likely be small in relation to total need. Nevertheless, fisheries has a role to play in feeding people and providing income; if some people can be fed or supported by fish, then fisheries science ought to see that they are.

The resource

FAO has recently issued the Indicative World Food Plan. Detailed drafts for most areas of world seas have been completed and form a data base for projections. This document, along with other papers produced by scientists in the last decade (Schaefer and Alverson, 1967; Ryther, 1969; Moiseev, 1969; Alverson, Longhurst and Gulland, 1970) provide some concept of the quantity of biological material available in world oceans. Although this debate will continue, the majority of scientists feel that from 120–200 million metric tons of fish and shellfish of the type now commonly utilized could be produced within the limits of existing technology. That is roughly two to four times the quantity of fish and shellfish now taken from world oceans (approximately 54 million mt in 1968). Considerably greater production might be achieved if man could develop technology that would allow harvesting forms from lower trophic levels.

Gross figures of regional production in the FAO IWP Report, perhaps more than anything else, document our shortcomings and ignorance as it relates to marine resource potentials. Further, they point to historical weaknesses in available methods of stock assessment. Most classical methods (Marr, 1970) are not really effective for the task. One of the real weaknesses of such techniques is that they do not provide contemporary information; and for the oceans, there is a definite lack of suitable assessment techniques for most pelagic forms.

Although we here do not intend to emphasize forecasting of future technology a few remarks concerning the problem of resource assessment are appropriate. It would appear that the greatest likelihood of success lies in developing sonar assessment techniques. Integration of returned echoes in conjunction with a means of identifying the target (perhaps using telemetered underwater television from a remotely-controlled vehicle) offers a realistic promise of obtaining stock data over wide areas within reasonable cost. For benthic resources acoustic holography offers much promise, but we hasten to indicate that it is unlikely to provide a panacea for fish identification and location for even modest ranges. However, we may be overly pessimistic as the potential of acoustic holography is only beginning to be realized. Much information could also be gained if a workable feedback method between commercial fishermen and scientists could be established. These in turn imply suitable navigation and electronic capability of the fishing vessels, coupled with team effort, a concept of fishing to which we will again refer.

The harvest

For the most part we hold to the forecast on technological development presented in 1963.

Out forecast concerning search and detection has not been radically modified in the past six years, although we hold that development in detection of catchable stocks could be greatly enhanced by cooperation between fishermen. It is unlikely that the necessary sophisticated equipment for optimum searching will be carried by all vessels. It seems reasonable, therefore, for a single boat in a fishing fleet to be so equipped and to provide this information to its cohorts. Looking somewhat further ahead it is possible that such vessels, using shipboard computers, of which there are now several, satellite navigational systems, and a combination of the various types of sonic gear, would allow guidance of the fishing fleet over and through many grounds not now fishable, as well as for such fleets to track given schools of fish and provide for the ability to return to pinpoint locations. A precise satellite navigational system exists and communication and sonar equipment is readily available. Consequently, all of the elements for the technical side of cooperative approach are available. What remains is to demonstrate to fishermen that cooperative ventures can be individually profitable.

The feasibility of relating the distribution of certain commercially harvestable stocks to water properties detectable from satellites has been demonstrated by Lindner and Bailey (1969). Altough we expect that satellite detection of certain hydrographic phenomenon will be helpful in forecasting, it will be limited to relatively few species and further evaluation of the potential of such systems is required before we are willing to concede they will be playing a major role in governing fishing strategy.

Our earlier forecasts on the general feasibility of using underwater acoustics for search and identification stand. Though much improvement has been made in short-range devices, the only recent advance has been the development of the side-scanning sonar which would permit more detailed data acquisition. Employment of coherent light (laser) is proceeding slowly; it is likely that this technique, combined with underwater television, will provide a means of underwater search with minimum backscatter.

We expect many technological changes in gear and vessels to result from the concept of modular design and interchangeability. This may be particularly true for smaller coastal vessels (less than 120 ft in length).Though telemetered equipment and tow tank tests have materially aided advances in gear design, there is still a great void in theoretical studies of the nature of hydrodynamic flow about net surface. Mathematical modelling of such problems and a fuller understanding of fish behaviour in relation to gear will bring about further developments such as the fast-sinking purse seine and shrimp separator trawl recently innovated by the U.S. Bureau of Commercial Fisheries. This gear was a result of combining both theoretical and empirical knowledge.

The recent increased use of pots and traps to exploit crustaceans and fish almost seems a retrogression in terms of fishing technology, yet this passive technique provides a number of economic inducements. Development of

advanced high-speed hydraulic winches and new over-the-side-handling techniques for fishing traps has provided a means by which fishermen can distribute a large number of units in an effective geographic pattern, retrieve them, rebait them, and reset them in a short time span. In fact, some vessels can effectively haul 60 single pots per day from water depths exceeding 200 fm. Fishermen estimate that by utilization of longline techniques for pots up to 300 pots per day could be successfully fished. Although the catch per pot is normally quite small, high per day total catches can be maintained. Using pots to harvest a variety of marine resources reduces labour and increases the boat share.

While lauding technological developments in gear development, we caution against continued introduction of non-destructible and equally unrecoverable harvest implements. We are concerned that the effect of lost gear, particularly on benthic stocks, may be sizeable and account for the observed declines in a number of crustacean fisheries. There is growing evidence that such devices not only continue to catch the animals for which they were intended but a wide variety of other organisms.

Our views on ranching the sea remain much the same as in our earlier paper. In spite of publicity given aquaculture, we feel that except in local geographic instances success in the next decade will be limited. Even with major engineering efforts aquaculture will probably remain as a medium for high-quality, high-priced protein products for some years to come. We do not, however, wish to be closed-minded in this regard and challenge the proponents of aquaculture to prove us wrong. Indeed, we hope they are right. Until such time as aquaculture can cope with producing low-cost protein, herding and controlled distribution of natural stocks would seem more easily accomplished. The development of passive gear suggests the possibility of much larger "pots" or corrals for harvesting certain migratory demersal and/or pelagic species. It seems peculiar that we have not yet utilized the fact that large quantities of biological material (e.g. hake) move through rather restricted geographic zones during certain periods of the year. There is no reason to suspect that man could not tap off this flow of material and harvest desired quantities. With the possible exception of krill and swimming crabs, it is evident that harvesting plankton at the present time cannot be economically accomplished. The concept of ranching seems to be a more effective way for man to use oceanic plankton through the food web. Of course, a number of difficult biological and technological inhibitions must be resolved. Although the initial loss of such a system may be quite high, over a long period it may have advantages through replacing large numbers of fishing units. Such a system also may be dependent on establishment of new legal concepts as they relate to utilization of seabeds. We still believe that both mariculture and ranching might gain considerably through understanding of the ability of fish to detect and distinguish between various odours. The state of the art has recently been reviewed by Kleerkooper (1969). As we earlier suggested, the key still appears to be in the development of filter-bridge fences for the containment of desirable species.

Product use

A number of recent review papers have considered processing technology and marketing. In spite of considerable progress in automation and engineering, there appears to be no major advance on either front. Indeed, application of some of the technologies, such as quickfreeze techniques and radiation preservation, appear to have come almost to a complete standstill.

The trend towards using fish products for high protein fish meals has carried into this decade and is likely to continue. Efforts to resolve the fish protein concentrate problem and its distribution continue. For all practical purposes the technology of production exists but the acceptance of such additives to food products seems a long way off. Food acceptance by humans is indeed an irrational process. One can only hope it would provide an incentive to the "innovative" communication groups. We believe this problem warrants serious consideration as alleviation of hunger will require operations for the most part in tropical areas. The use of marine protein concentrate seems to be the only practical means of supplying such food additives in regions where adequate transportation, refrigeration and sanitary facilities are limited.

Perhaps one of the more important trends in the use of fish will be in the formulation of "amorphous" protein, that is, fish treated in such a manner that the extracted protein will be put into any number of food forms having various textures, colour, and taste. Experiments, in this area, of course, have been underway for some time, and we anticipate that utilization of fish protein on a commercial basis for this purpose may be realized within the next decade.

PROBLEMS CONFRONTING THE FUTURE OF FISHERIES

Although fisheries production has increased at a rather steady rate since the end of World War II, this success has not been achieved without manifestation of a number of problems. The historical record of national and international management of resources is not very satisfactory. Resources have often been over-exploited and fisheries have passed through the "boom and bust" phase.

Obviously, the degree of success that one might expect of management is dependent on the degree of understanding of the basic processes and the predictive precision of one's model. The piecemeal approach is nowhere more evident than in the field of management and a total system concept must be incorporated if management is to be anything more than chaos.

It is important to note that recent failures in national and international management of fisheries resources have not necessarily resulted from a lack of understanding of resource behaviour. On the contrary, it appears that at times failure has resulted from the attitude that management decision can only be made on the basis of complete understanding—which is itself an irrational philosophy. In other instances the failure seems to have resulted from lack of an effective institutional system which will allow implementation of required management. An increased

data base can help immeasurably if the information on stock trends are current enough to allow timely management decisions to be implemented. If it is to be effective, we must have a preventative management system rather than management which is remedial in character

Management cannot be predicted on biological factors alone. Most of the legal, economic, social and educational questions have not been tackled on a broad base; and, indeed, effective management must consider these non-biological areas. To understand the management problems uniquely associated with fishing, it is necessary to recognize that this industry represents the only major remaining food producing system in the world which relies on a hunting procedure, exploits wild stocks, and must utilize resources that are considered the property of all sovereign nations.

The consequence of over-capitalization in a particular fishery or set of fisheries is extreme pressure on management groups to relax the nature of the regulations in terms of season quotes and/or to encourage regulation which eliminate the more efficient units. Frequently, this type of management has resulted in degrading the efficiency of the harvesting system and often has not provided the physical protection the stocks require. A number of general solutions to the "fisheries problem" have been proposed.

What is needed is an effective way of implementing proposed solutions without destroying current economic momenta or dispersing the new regime in a fashion that is unfair to that existing. This implies a considerable educational programme and development of legal policy. We abhor the unilateral national approach as unworkable and potentially dangerous both to the resource and to mankind. While not underestimating problems of practical negotiation, one would point to the efforts of Canada, Japan and South Africa toward the problem of limited entry to the fishery.

The circular approach to management problems and to the decline of resources so common in the past must be eliminated. Every segment of the system seems to be at least in partial fault. The fishermen, processor, and often those responsible for management, fail to respond to early warnings of resource depletion. The warnings of the biologist, economist or lawyer never seem to be heeded until it is too late and then miracles are expected overnight. The scientist must accept part of the blame because of his reluctance to recommend or predict on the basis of incomplete data. If complete data were available, there would be no need for the prediction. Much of the problem here seems to stem from a lack of understanding of the difference between the roles of science and management. This is rather well put by Gulland (1970): "Management is a matter of taking decisions, and often it is at least as important to take a decision in time as to make precisely the best decision. Management has to resolve a wide range of often conflicting objectives, of a political, social, or economic nature. Science has to provide evidence on the likely results, within its field of competence, of possible management actions, and so enable more rational decisions to be made." In a sense management failure may partially be the result of adopting the scientific method as a requisite for decision; that is, rigorous proof that a statistical condition prevails. A decision in management is a value judgement and must be made on the basis of information available.

Much fault lies with government which often tends to ignore overall management responsibilities, or is unable to implement them. As a consequence, many resource management agencies are losing credibility. The fact that an international or government organization is managing a resource and has a staff of "experts" is no longer sufficient authority for a course of action. Separate and independent analyses of data will be requested by the public, and where necessary, legally insisted upon. This should not be surprising as it is a natural consequence of an informed public and a measure of the (lack of) success that we have attained to date. The public sector and political unit fails to provide support, which paralyses investigation until the situation becomes critical, then, because of the interrelationship of many problems brought in on the periphery, solution is often difficult, costly, and time-consuming, if not impossible.

Let it not be implied, however, that we think the only problem in communication and education is at the organizational level. The contributions of fisheries science are a function of the competence of the individuals involved. The question of educating or updating of fisheries administrators and biologists is equally pressing. A number of managers and executives are experiencing psychological effects from the realization that they are "burned out". These individuals have become, over time, incompetent to perform at the level for which they were once adequately trained. To be brutal, they are obsolete and contribute to the overall dilemma As a consequence we forecast mid-career education and re-education as becoming common-place; indeed, it is the only remedy in areas such as fisheries where the number of scientists is still in short supply.

Effective implementation of management does not depend on a utopian or idealistic concept but upon a method of costing and evaluating options open to the public sector and on the capacity to implement a decision. Contemporary management must go beyond the single resource and concern itself with the multiple pressures on the environment. For example, we cannot assume that pollution problems will be resolved in time to maintain present biological production. Indeed, man's multi-purpose needs for the water environment, for transportation, to exploit its mineral potential, to develop it for real estate and industrial purposes and to use the ocean to dispense his waste products, increases the likelihood that we will ultimately degrade the general biological productivity of the sea. The very seriousness of this last named problem is going to forcibly bring about effective mechanisms of interaction between cognizant agencies.

While these comments on factors which influence trends in fisheries are somewhat ominous, we nevertheless take an optimistic viewpoint and forecast that international management problems will be largely resolved within the decade and that they will ultimately incorporate decisions based on biological, economic, and social factors.

Future developments are likely to be sharply influenced by the ultimate resolution of coastal state jurisdictional problems in the oceans, but it seems likely that regional

fisheries bodies will evolve, which will have dominant roles in establishing management systems. Such regional bodies will likely provide a high degree of protection to the local coastal states within the geographic sub-divisions for which they operate, and allow for incorporation of limited entry concepts, which could attract new capital into the fisheries, accelerate development, and provide incentive for increasing efficiency of the harvest system. If such conditions prevail, it is safe to forecast a realistic transition of fisheries from a hunting procedure to one of range management using the community of animals available.

In our earlier published paper, we suggested that advances in fishery harvest were not limited only by existing technology but in basic gaps in basic biology. We now see this to be only partially true and that questions of a legal, economic, and social nature are equally, if not more, important today. We further suggested that one could find refuge from this apparent revolution by recalling the conservative nature of the fishermen. This security blanket can no longer be condoned, for time is against us and it is apparent that the fundamental responsibility of the fishery scientist can no longer be ignored. It behoves the fisheries community to develop an analysis of policies and their implication on technological development and trends in fisheries. Because of the nature of national commitments it would seem reasonable that the first assessments should be made with a total international viewpoint. Perhaps implementation of such an effort might be a laudable objective of FAO or some international foundation.

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DISCUSSION

FISHING IN THE FUTURE

Alverson (USA) Chairman and Rapporteur: Some of you will recall a similar session on Fishing in the Future at the Second FAO World Fishing Gear Congress in London, 1963. For this, **Kristjonsson** had asked **Wilimowski** and myself to prepare a paper on developments in fishing gear technology that we might anticipate during the next several decades. I recall that the paper had various descriptions, e.g. futuristic, science fiction, fantasy and some even more caustic in character. Since the London meeting I have had the opportunity of reading several books related to technological forecasting, and although my understanding of the criteria on which to base future trends may have been broadened at the same time I have raised doubts that I have the adequate training to provide this conference with an analytical look into the future. **Wilimowski** and I therefore accepted this new assignment with some trepidation.

Before we start this crystal ball session might we go back to the congress in London some seven years ago. Those who were there might reflect back on some of the forecasts made at that time and consider them in the light of what has happened in the last seven years.

One of those forecasts related to the evolution of satelite systems for both navigation and acquisition of oceanographic data of value to fishermen. Certainly we have made considerable progress in that particular area. Forecasts were also made, which at the time were thought rather amusing, of a possible breakthrough in use of lasers that could be used to search through the air-water interface without a great loss of energy. Recent experiments in the blue/green part of the spectrum, have successfully detected targets down to depths of about 100 m. Numerous forecasts were also made regarding the possibilities of fish aggregation, and in the last six years there have been a number of advances using physical and mechanical techniques. Finally we suggested the evolution of fish forecasting centres and although these do not yet exist (in the true sense of forecasting) a lot of thought is being given to this possibility and perhaps by the time we meet again such centres will be in existence. Some of the forecasts made at the London conference now seem rather unlikely to occur but like the gypsies that read the palm I have told you only about the successful predictions. I will remind you, however, that the London paper looked 30 years ahead which gives us 23 years more tenure.

It is appropriate that for the topic Fishing in the Future we examine all contributions to the congress and from them try to forecast the path of fisheries in the next decade.

Let us start with looking at the problem of locating fish using environmental measures or clues. I am very pleased to find that some scientists have finally caught up with fishermen in understanding relationships between thermal fronts and fish distribution and this after some 20 years of rhetoric. Although this may sound a little caustic, I believe WMO, IOC, ICES and the multitudes of oceanographic and fisheries organizations that hide under various anachronisms will effectively bring themselves together during the next decade and develop a forecasting system helpful to fishermen. To do this it is important that marine scientists establish environmental relationships that are pertinent, that oceanographers establish in a quantitative way the importance of meteorological events and finally that we must move from "historical" forecasting to anticipating events. Regardless of these problems, by the end of the decade there will be several such fish forecasting centres in the world which will pull together information from the fishing fleets (using them as sensors) together with various meteorological data and will provide time relevant information which will assist fishermen in

positioning themselves in areas where there is a high probability of detecting commercial fish concentrations. In a successful venture the *fishermen will be an important link* in terms of information transfer between vessels, within the fleets and to the data centres.

In the field of fish detection I anticipate the following. We will have improved reliability in echo sounders and sonars and there will be a simplification in terms of echo display. We might anticipate some increase in range through the development of non-linear acoustic techniques and improved signal processing which will allow for more effective evaluation of biological targets detected. I also forecast that a method of rapid target identification will be developed within the decade and I anticipate special purpose computers that will take information from the sonar or echo sounder, evaluate the echo signals in terms of relevant information stored, and forecast to the fishermen whether or not a successful set can be made. To be effective the system will require an input of environmental data to eventually make corrections for environmental anomalies or at least tell the fisherman whether or not he can consider that the observations are reliable.

Although sonar and echo sounders will continue to be the major systems used for fish detection other "unsound" techniques will come into use. Indeed, during the next decade **Sams** will still be in the picture with his aircraft and there will be an extension of this type of activity. There is a possibility that use of biological light detected by image intensifiers might find application in certain areas of the world and satellite observations of large scale oceanographic events will be helpful in locating productive fishing areas. This will not be a direct observational technique but will examine phenomena in the ocean which influence fish distribution patterns. Finally, in the terms of search (at least for research vessels) underwater television and photographic techniques will come into greater use. I am not so sceptical about the possibilities of using remote controlled acoustical devices as some other speakers. My comments are confined to vertical search where a transducer could be placed in relatively small automated vehicles, e.g. 10 ft in length, which could be operated from a research vessel and retrieved quickly after the observations were made. The new Norwegian Research vessel *G. O. Sars* cost four million dollars to construct. It doesn't seem out of line to consider a 10 to 20,000 dollar remote controlled vehicle that could be programmed on a parallel course by radio control. Such a system could greatly increase the number of observations made. However, for the next decade such systems if used will be confined to research vessels.

In purse seining we will see larger nets and specially tailored nets. Special purpose nets designed around the behaviour characteristics of fishes will resolve the problem of fishing for tropical tuna. **Kristjonsson** has related how improved tactics can result from better interpretation and use of sonar equipment. Finally, at the next congress the argument on using and not using skiffs will still be with us.

In the area of trawling there will be a greatly increased emphasis on aimed trawling. At the risk of being considered a heroic, I do not foresee any striking breakthroughs as a result of studies on dynamics aspects of trawls. The great advances in trawling that have occurred over the past several decades resulted from changes in tactics and the capability of precision setting in the terms of positioning, that is better control of the net in relation to detected targets. During the next decade we will have increased control in terms of aimed trawling and perhaps control in shaping the net during towing according to the types of echo sounder or sonar traces.

I am a very strong advocate of multi-purpose vessels. Other speakers have stressed the importance of having the ability to switch in a geographic sense and in a gear sense to other resources as the need dictates. The design (house forward or aft) in a multi-purpose vessel is not as important as having adequate power and deck handling facilities, to accommodate a variety of fishing systems. There will be more and more multi-purpose boats in the future. Even now there are vessels that (within one year) operate in four different fisheries. The use of roll stabilization devices aboard fishing vessels will increase.

At the 1963 Gear Congress the importance of aggregation techniques was discussed. I am still convinced that for the exploitation of latent resources in the ocean, many of which perhaps do not have distributional features suitable for easy harvesting, the knowledge of behaviour and response to certain stimuli will be important. Harvesting of such forms may be accomplished by "passive fishing", that is allowing the fish to provide the required motive force when coming to a certain collection device. The fisherman's purpose at that point is to get him out of the water. All of us are aware that trap techniques of this type date well back into history.

The use of light and pumps as reported by the Russians is now being used in several areas of the world. **Green** made a comment several days ago about light studies in the capture of squid. Delegates may not have appreciated the importance of his remarks which outlined an extremely interesting result. Experiments had been conducted for several days on using a light and pump in which the intake was positioned vertically downwards. Somebody got the bright idea to tilt the light horizontally and use a funnel shaped device in front of the pump intake. The catches jumped from very small amounts to 40 to 80 tons per night. The squid may represent one of the large latent resources in the ocean and this experiment is significant because it allows us to consider a passive technique for their exploitation. In the long run fishing must pass from the hunting stage into some sort of range management concept or coraling system and this is possibly one indication of how we can achieve that. It is only one of a number of possibilities.

In some areas of the world there is a very rapid transition to pots for the capture of a great number of crustacea. Although this may seem like retrogression as men were using pots when they first walked out of their caves, on the other hand it has some advantages in that small numbers of people can, with modern hydraulic equipment, handle a large number of capturing units, e.g. on a longline system up to 300 pots a day. The idea of exploiting certain high value fish species with this system has recently been introduced into the Pacific North West. We are all familiar with the fact that large traps have been used to harvest salmon and a good number of other species that swim near the surface. We now also have rather good information on the behaviour and migratory patterns of some demersal species. As an example along the West Coast of the United States large concentrations of hake move up the continental shelf in a very narrow band from 5 to 10 miles wide. The flux of material across a line normal to the coast might be as much as a billion pounds in a one month period. The floating capital now there in terms of the USSR fleet may be as much as half a billion dollars. It is possible that we can develop traps on the seabed which could tap off a large amount of fish for a far smaller investment.

During the next decade behaviour studies on fish will provide us with a great deal of valuable information which will assist fishing activities. I don't think we have adequate information, for example, on the problem of noise to know what to design for, if it is important to design vessels with certain noise limitations, or whether or not certain acoustical patterns can actually aggregate or herd fish. At the Bergen Conference we heard a very interesting report from the USSR on acoustical herding in which large schools of cod and herring were moved to the seabed effectively. I hope we might get some comments on further experiments from the USSR.

Modelling will continue in all aspects of computer simulation for the purpose of training and for the purpose of giving information on optimisation of both vessels and fishing gear strategy.

In spite of the fact that this is a technological conference we cannot divorce its activities from one specific environmental aspect, namely the jurisdictional environment. It is not the purpose to discuss jurisdictional problems here but it should be kept in mind that this may form a new background in which fisheries may have to operate in the future. There will be conferences within this decade to deal with this issue. If extended jurisdiction is manifest, then the whole concept of fishing itself, in terms of the types and character of vessels used, may be altered.

I would caution that we cannot avoid looking at the problem of how we utilize our aquatic resources. Many people come to technical conferences of this type thinking that technological innovation is antagonistic to good conservation. This is of course not true. Technological innovation really has no particular bearing on conservation, if those who study and are responsible for making decisions manage the resource on a timely basis. The problem is of course institutional in character, in the derivation of organizations which can act in a responsive and timely manner. There is also the whole problem of the ocean as a receptacle for waste products and whether or not we will maintain its biological productivity. Despite the fact that we have had some very strong sceptics mostly in the USA, I forecast the oceans can provide additional food. We will have increased fisheries production as a result of the diversification in the number of fish species exploited and from improved technology that will allow us to harvest a number of resources that we cannot now effectively use.

I was encouraged by a number of people to say that within 20 years all fishing boats will have computers. Should we follow this to its ultimate conclusion it is quite obvious that **Laevastu's** master computer may be sitting in Rome and that cybernetics will proceed by that time to a point where we will no longer need fishermen. Also, we will no longer need biologists or fishing technologists and we will have no more conferences of this sort. But this is indeed fanciful. The fisherman will certainly continue to be the key element in the effective exploitation of aquatic resources.

Hjul (UK): Are there any ideas on how to exploit unconventional resources like krill. For instance, do the Russians have any plans on how to capture them?

Freedman (USSR): I think it would be better to discuss this problem on another occasion.

Gronningsaeter (Norway): Krill is being fished in Norway on a small scale with lights and also with surface floating trawls. The catch is frozen and commands a good price as food for raising salmon.

Craig (UK): Does the Rapporteur see fishing vessels continuing to carry their own fish home from the fishing ground in the future, or does he expect an increased trend towards fish carriers and fleet operation.

Alverson (USA) Chairman and Rapporteur: I expect the multi-purpose medium sized vessel to dominate fishing activities for a number of years and only if there should be major jurisdictional changes, i.e. substantial extension in national limits, should I anticipate there being increased scope for large scale mothership high sea operations. But nevertheless the smaller multi-purpose vessel fishing for itself will remain in the system.

Dickson (FAO, Poland): Vessels are getting larger and more powerful. Nets are getting bigger and the trend seems to be to tow slower.

In certain areas where there are stratified current layers there must be vast reserves of power in the ocean. What about utilizing this by putting one big net in one current stream opposed by another net in a different water layer?

Alverson (USA) Chairman and Rapporteur: There has been a forecast that it would be possible, by using the motive force of a current, to collect those smaller organisms such as krill. If one could develop a holding mechanism one could actually screen off such organisms like collecting carbon on a sheeting. I have no idea about the practicality of this.

Stevenson (USA): There is a study in the USA to determine whether the energy of a specific equatorial current could not be utilized to generate upwelling of cold high nutrient water and thus raise productivity in otherwise unproductive areas.

Green (USA): A paper presented by the USSR scientists at the Bergen Behaviour Conference reported on experiments using artificially created predator noises to drive bottom fish into the path of a trawl. I would like to know if there is any further information on this.

Freedman (USSR): This is still in an experimental stage and the results are not yet conclusive.

Alverson (USA) Chairman and Rapporteur: In a personal communication from the USSR I was told that difficulties had arisen with this system due to high equipment costs.

Green (USA): I have heard that a Japanese firm has produced a similar system for transmitting the sounds of frightened bait fish schools into the water to attract tuna and mackerel. This device is said to be on the market.

Cunningham (New Zealand): In New Zealand we do not use sound to attract fish but to detect fish. Noise of fish schools is recorded by sonar buoys and the fleet is directed according to the recordings. Use of recorded noise for attraction purposes is still in the experimental stage.

Hamlin (USA): I would suggest that in the future at least half of the delegates to this type of conference should be crew and officers of fishing vessels. This should really make it possible to exchange experience and to discuss practical points.

It is my belief that in the future we will use vessels with speeds up to 100 knots. At zero speed, fishing platforms may be developed on which even processing of the catch could be done. At present lobster boats with a speed of 35 knots are in use to reach distant fishing grounds. We might even end up with hovercraft. I think this new development should be studied by models and computers to keep the development cost low.

Alverson (USA) Chairman and Rapporteur: There are 50 to 70 fishing skippers registered as participants to this conference.

Engvall (FAO): I would like to bring up again the subject of systems analysis, because I believe that it will play a most important role in the future. It may be applied to smaller investments in single vessels or shore facilities or on larger integrated fisheries industry development, but also on the research and development schemes forecasted by the chairman in order to achieve the most efficient utilization of the available resources.

One illustration of the present uncertainty and need for better methods is the following. Three consultants made a study as to the most suitable size of wet fish trawler for Greenland. The only specification was that the fish should not be kept on board more than six days before landing. On the basis of the same existing data on catch rates and other relevant information, three solutions were worked out inde-

pendently and resulted in one proposal for a 300 gross tons vessel, one for a 500 tonner and one for a 1,400 tonner. I have great difficulty in believing that these three vessels would be equally economical.

Systems analysis of catching operations and the fishing industry as a whole has been undertaken in many countries and as far as I know practical experience is available in Poland, UK (WFA), Norway (Bergens Mekaniske Verksteder), USA (BCF) and Canada. There is a great variation in lines of approach and I fully agree with **Hamlin** that it is time for workers in this field to get together to discuss the problems and desirable future action.

In FAO, systems analysis was started with the aim of establishing a computerized evaluation model for fishing vessels to be used in connection with FAO's field programmes in developing countries. The first practical application was carried out in Peru on anchovy vessels. As this fishery is highly developed and expertly operated by large companies with own resources for evaluation of the operations, the results of our study did not indicate that the present development as regards the size, should be drastically changed but rather confirmed the sense in the present trend.

In this particular case the evaluation model may be more useful for the administrators dealing with management and regulations of the fishery. The influence of a large number of changes of variables such as catch rates, number of fishing days and cost and price elements, can be simulated in a short time and the model is, therefore, an efficient tool for decision makers in their efforts to secure a sound development of the fishery.

The results obtained so far by using the computer model are promising, and the FAO work in this field will continue and presumably expand considerably.

Terms like systems analysis, operations research, simulation techniques etc., are today very much in fashion, and I agree with **Schärfe** that it is appropriate to warn against too high expectations on the results obtained by the use of these techniques. However, a systematic and integrated study will generally provide a more solid foundation on which investors and administrators can base decision making. One way of putting it would be that it enables these people to guess with better knowledge.

The crucial problem in exercises of this sort in fisheries is always the catch rate and it is absolutely essential to improve the feed back of data from the catching units to enable safer prediction for new investments and also tactical decisions for optimum utilization of available equipment.

Parrish (UK): I would like to endorse the emphasis that the Rapporteur gave in his summary on the importance of studies and proper understanding of fish behaviour for actually catching fish and making use of their behavioural characteristics in fishing them more efficiently. In particular I would like to emphasise the importance of this aspect in relation to mathematical modelling, and draw attention to the possible dangers that one may meet if proper understanding of the behavioural features of fish are not incorporated in the models, both in terms of optimising fishing gear and also in decision taking with regard to tactics and strategy. With reference to the Rapporteur's final point concerning the impact of technological developments and innovations on conversation problems, I agree entirely that technological advance and the problem of over-exploitation are not incompatible. On the other hand I think the Chairman and several of us have a great deal of experience of the way in which the bodies concerned with proper management of resources operate. I think that we must all bear in mind that with further innovation and respective increase in the efficiency of fishing operations the demand for a proper rationalisation of the two sides of fisheries development becomes more and more important.

Ben-Yami (Israel): The Rapporteur mentioned the suggestion by someone that in 20 years most fishing vessels may have computers. I would like to remind you that there are still parts of the world where I hope that in 20 years all fishing vessels will have engines.

My following remarks are by no means aimed at denigrating this most useful, important and so needed conference we are having here. We should, however, remember that the great majority of the delegates represent the rather richer part of the world fisheries, and that it is probably this part which will gain most profit from this conference. Saying this, we must bear in mind the great and fruitful work in the field of fishery development done by FAO in the developing countries. The gap, however, is still very large.

The 'developing countries' sent very few delegates, and in many of these countries the highly sophisticated and expensive vessels and equipment we have discussed here are hardly applicable under present conditions. Therefore, a separate FAO conference on fishing in the developing countries in the near future seems advisable.

In forecasting the future of fisheries, we have dealt with the vessel, the equipment, the environment, and the object of fishing. There is, however, another factor which must be considered, namely, the fisherman. The manpower situation in developed countries is, as far as fishermen are concerned, far from satisfactory. In some places, the average age of the fisherman becomes distressingly high. Young people are not interested.

The technology while designing the fisheries of the future, must aim therefore on drawing college graduates to this profession. This, for two reasons: (1) more and more young people are able to obtain the higher education and they, soon, will form the majority of the available manpower in the developed countries; (2) people with higher technical education will be needed to run the increasingly sophisticated equipment on board. This can be achieved by providing suitable living conditions on board fishing vessels, by attractive wages, and by decreasing the number of days spent by each fisherman at sea. The latter can be solved by having large crews of which some remain ashore during each fishing trip, or, even, by double interchanging crews.

Kristjonsson (FAO): As you all know the biggest and costliest activity of the FAO Department of Fisheries is the introduction of modern fishing techniques and gear to developing countries. We firmly believe that there is only a difference of degree in scale and size, not a difference of types between what you should use in the developing fisheries and the industrialised fisheries. Many of the things we have been discussing here, are actually being introduced or tested in technical assistance projects in the developing countries, with promising and important results. Taking a non-FAO example, such as the German technical assistance activities in the Gulf of Thailand, there was no trawling some eight years ago. As the result of the work of **Engel**, who is in the audience and of an experienced German cutter skipper working with him, there are now 2,500 trawlers in Thailand and the fish production is five times what it was before. The high opening bottom trawl nets introduced are modern. They are light trawls which are big for the type of vessels that tow them and basically derive from advanced gear operated in northern Europe. Echo sounders are another example as is the early introduction of synthetics. I think it would be wrong to think in terms of one set of techniques and concepts for industrialised fisheries and another one for developing countries. Look what is happening in Ghana for instance.

Alverson (USA): A developing country is now the biggest producer of fish in the world and we in the USA are trying to adopt some of the systems they have.

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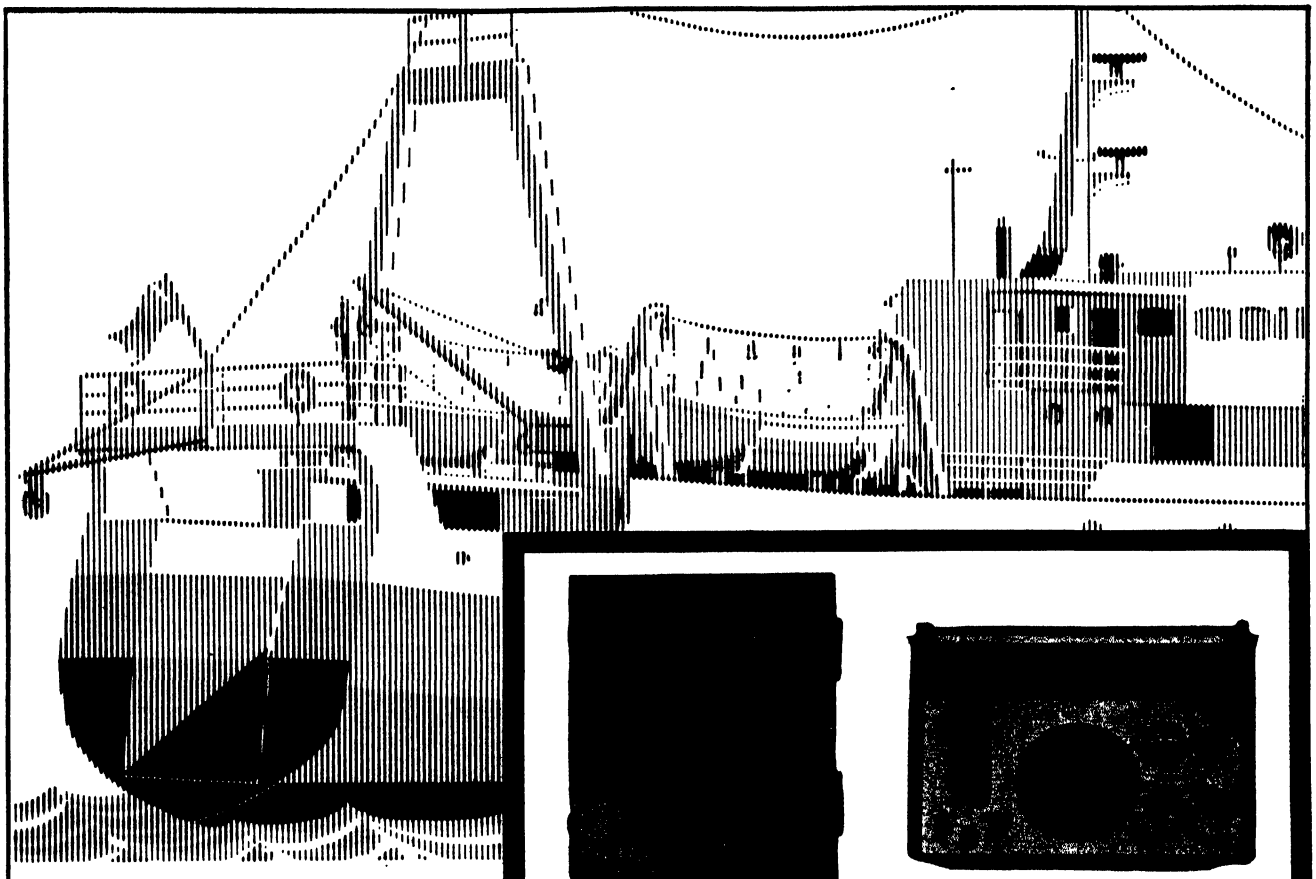

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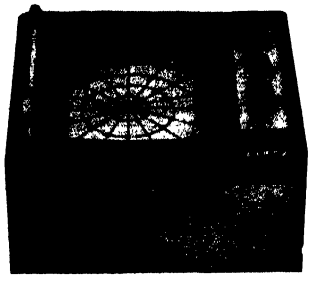

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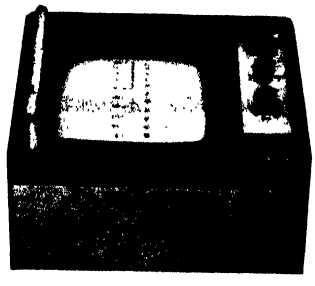

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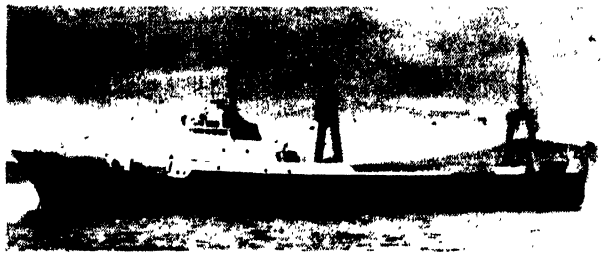

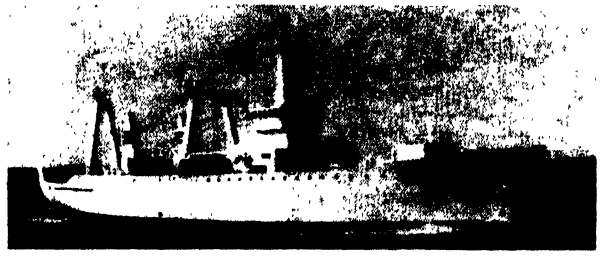

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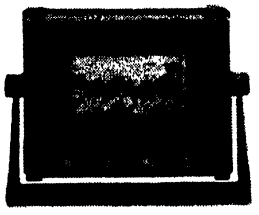

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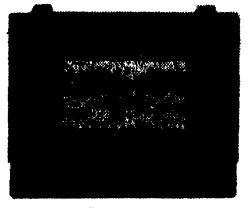

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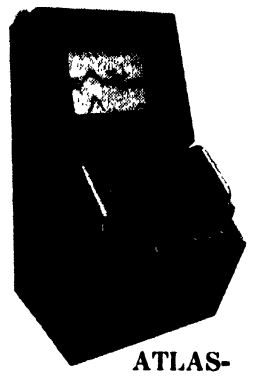

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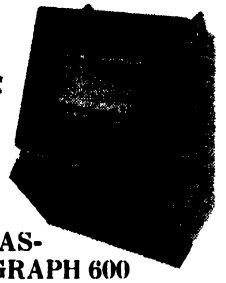

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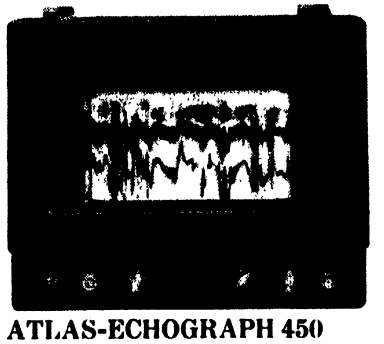

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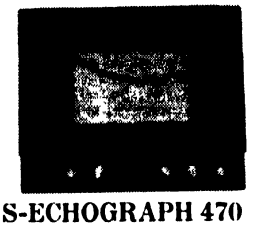

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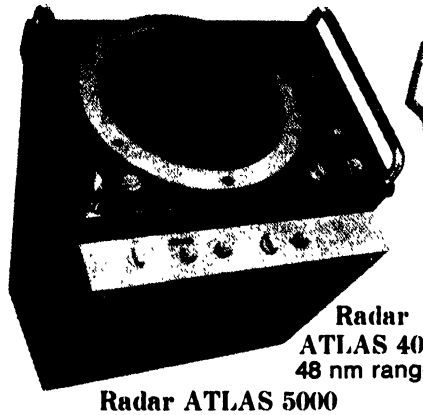

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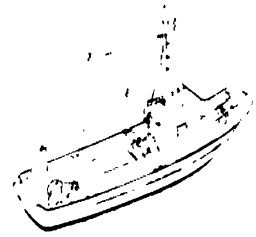

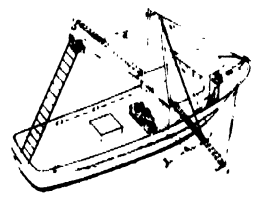

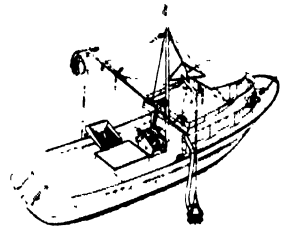

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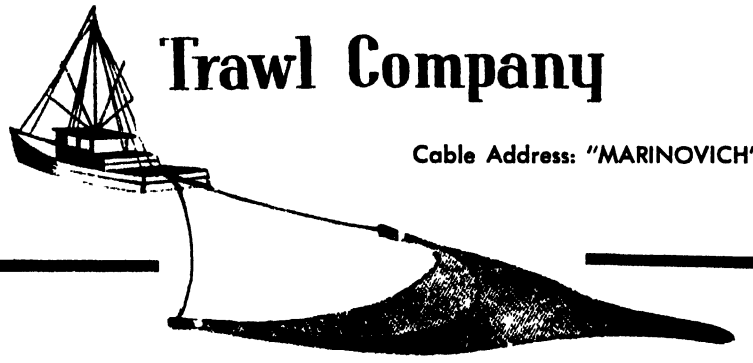

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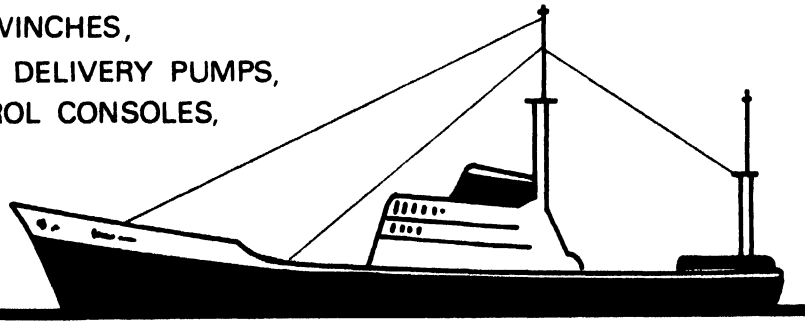

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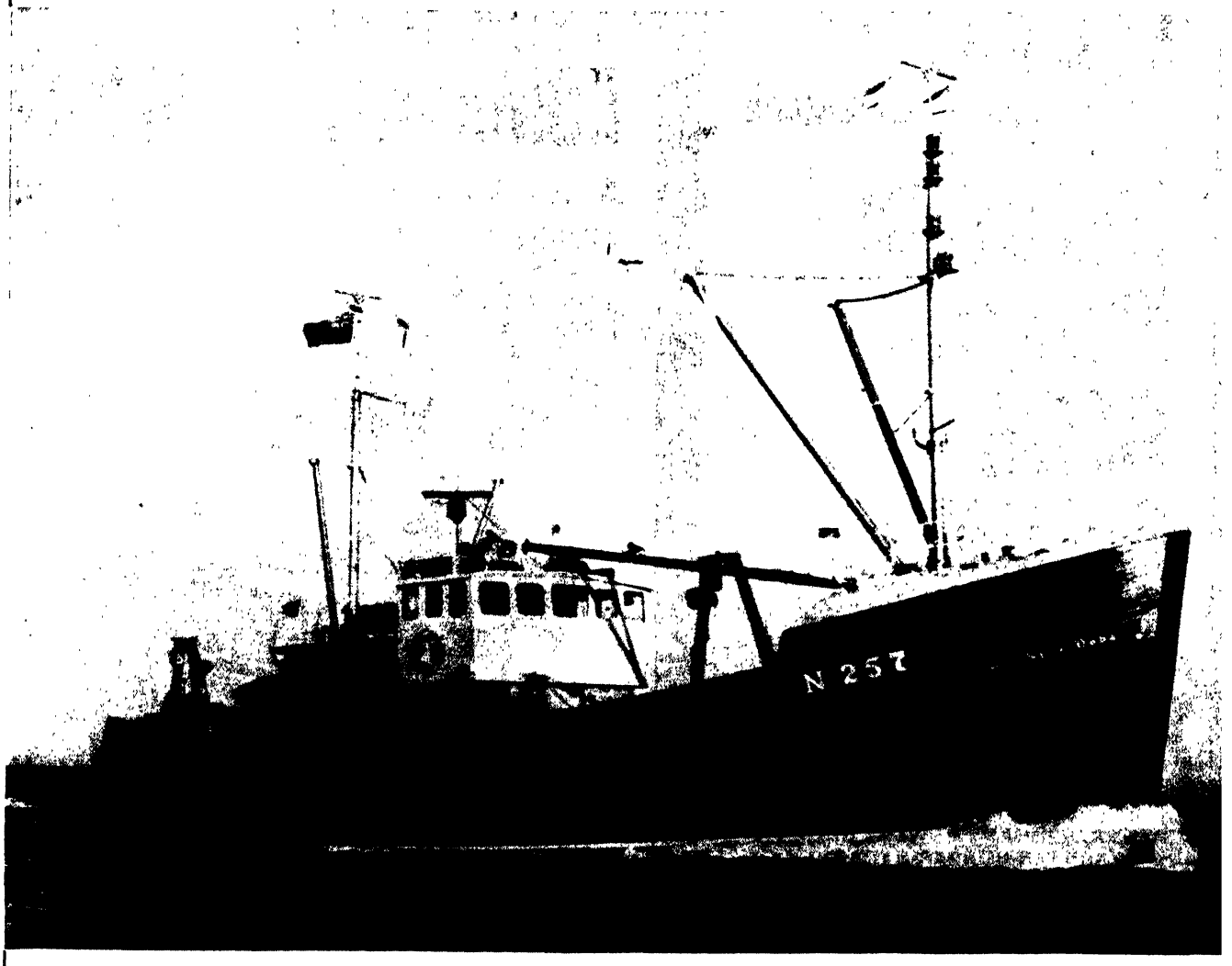

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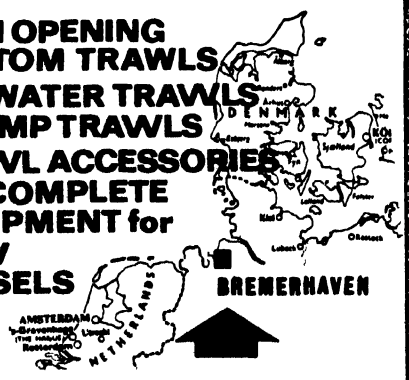

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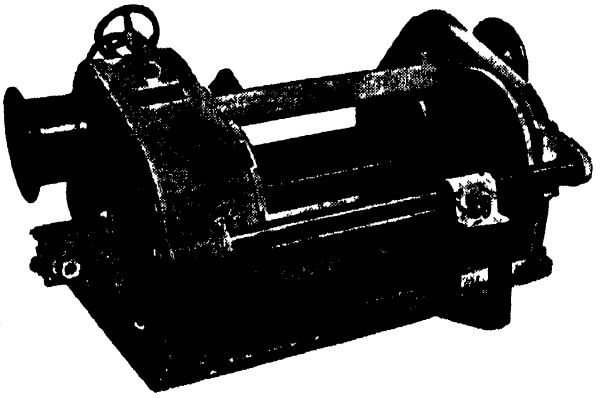

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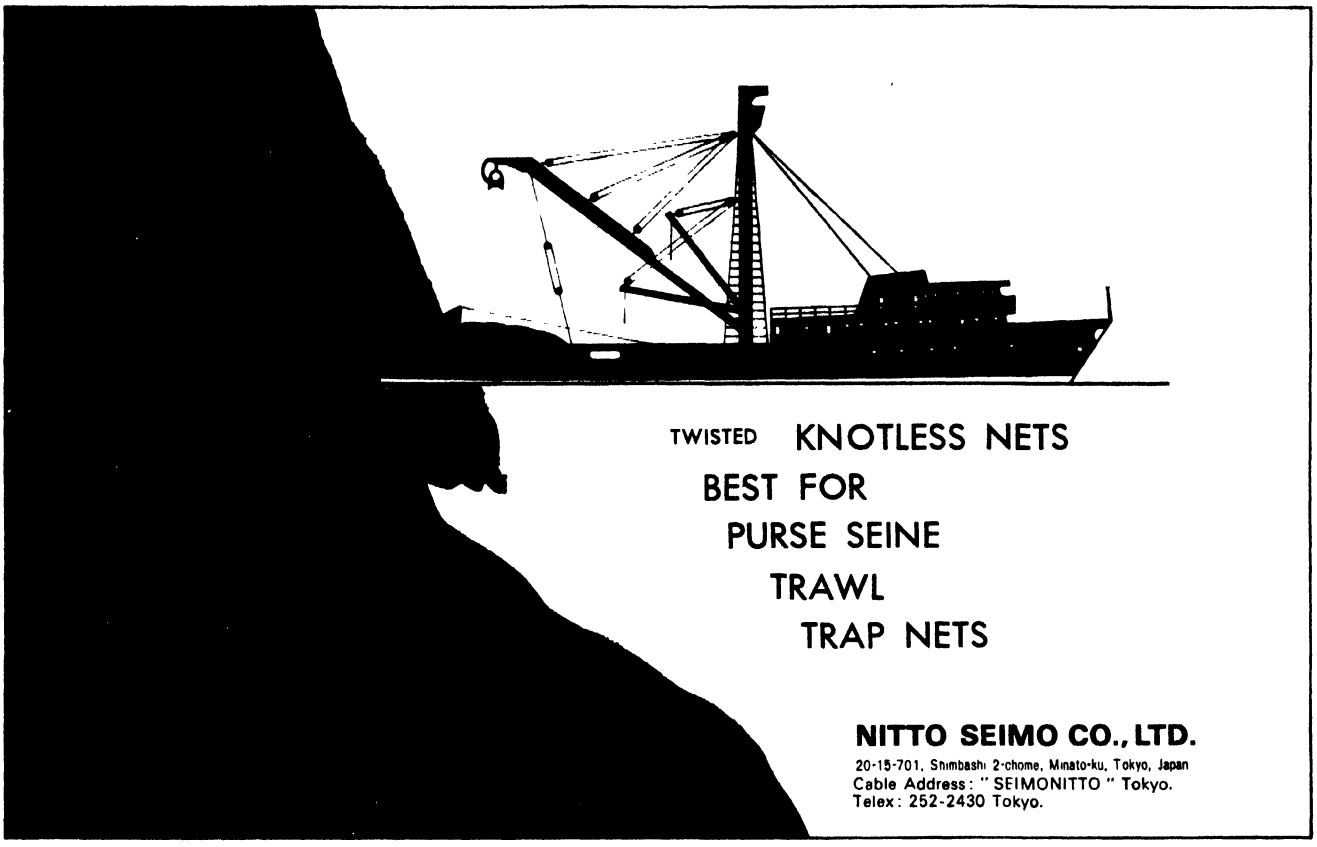

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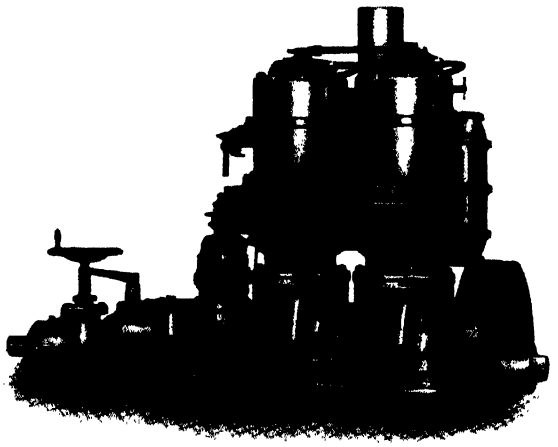

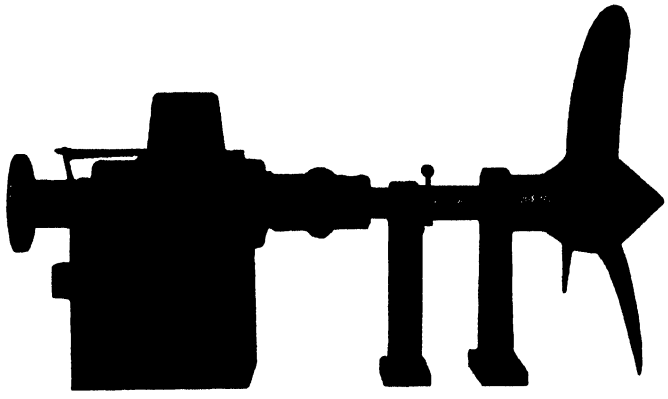

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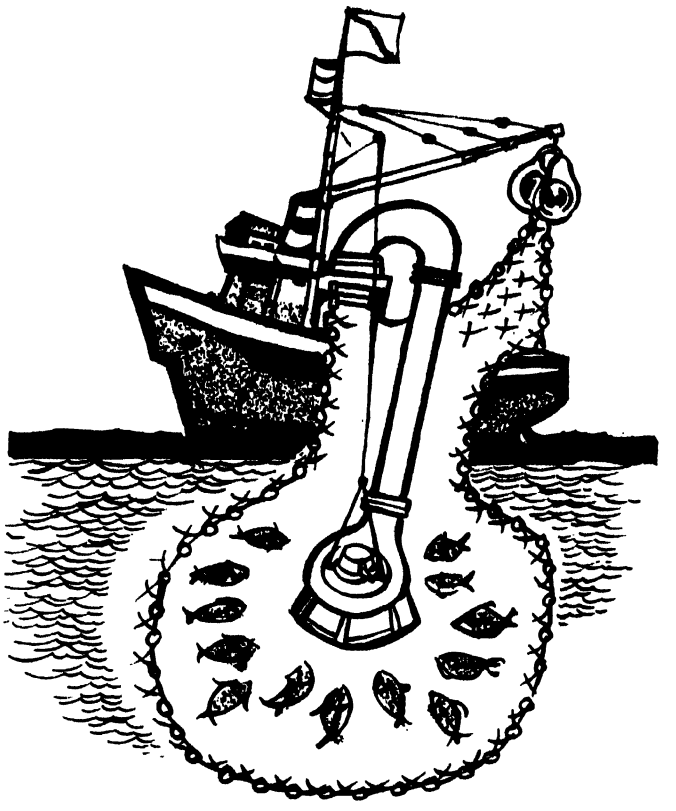

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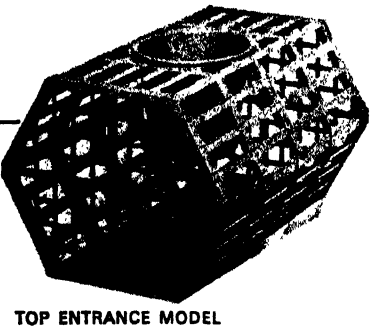

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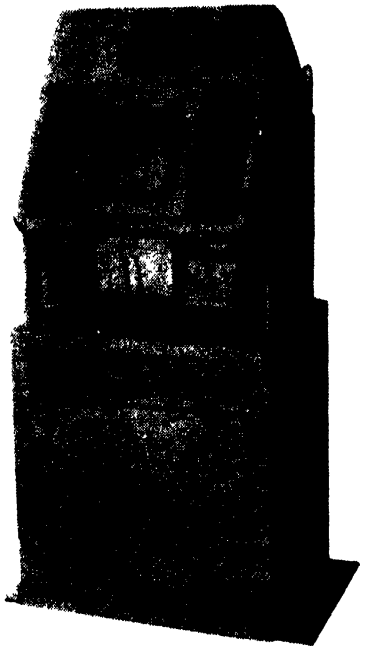

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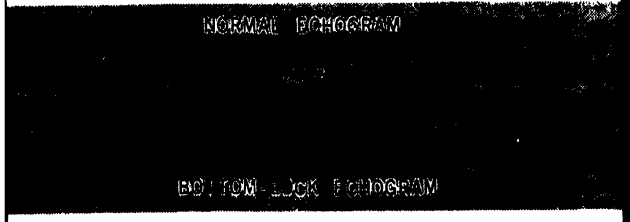

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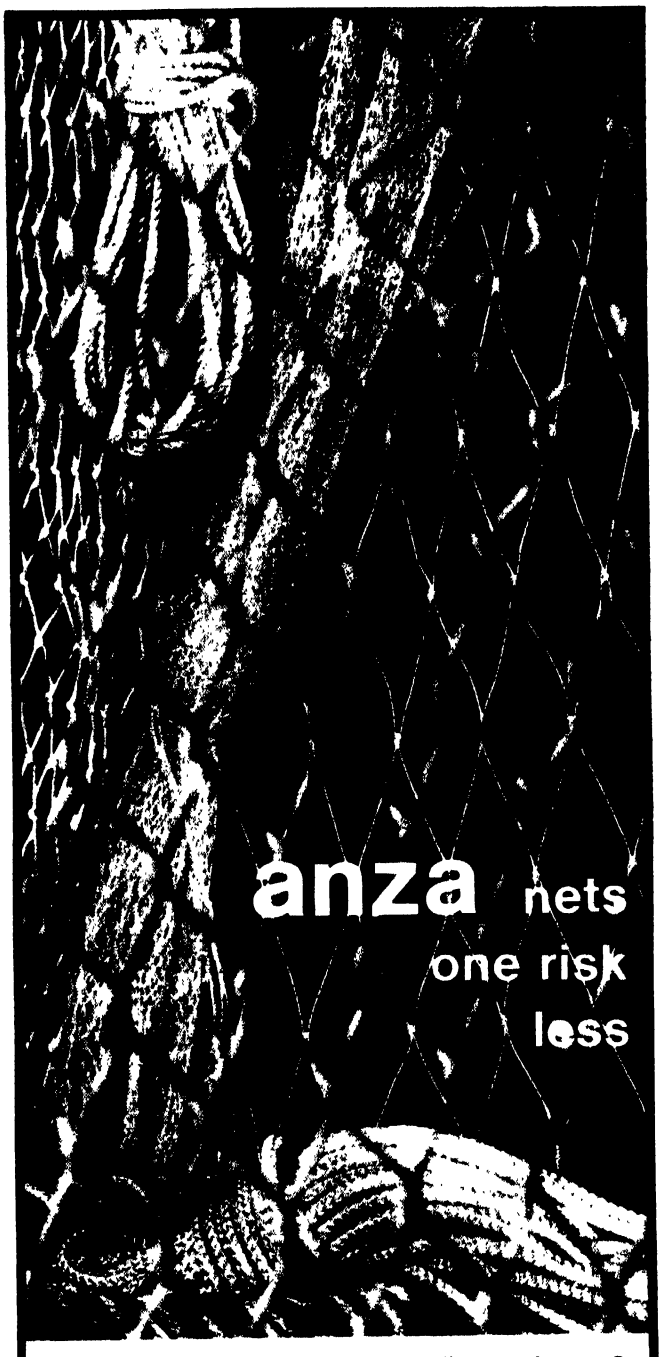

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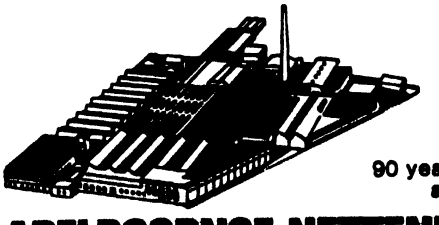

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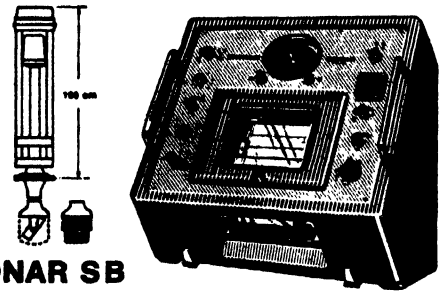

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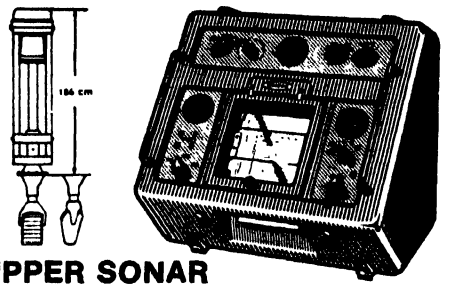

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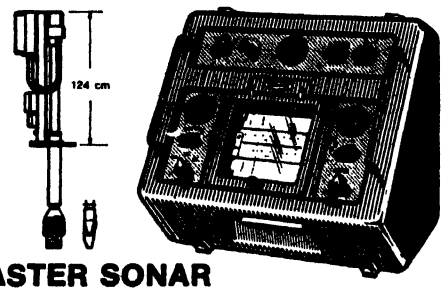

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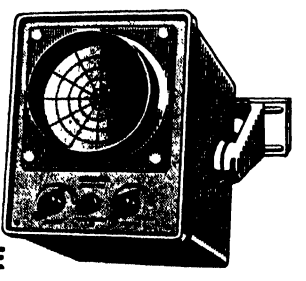

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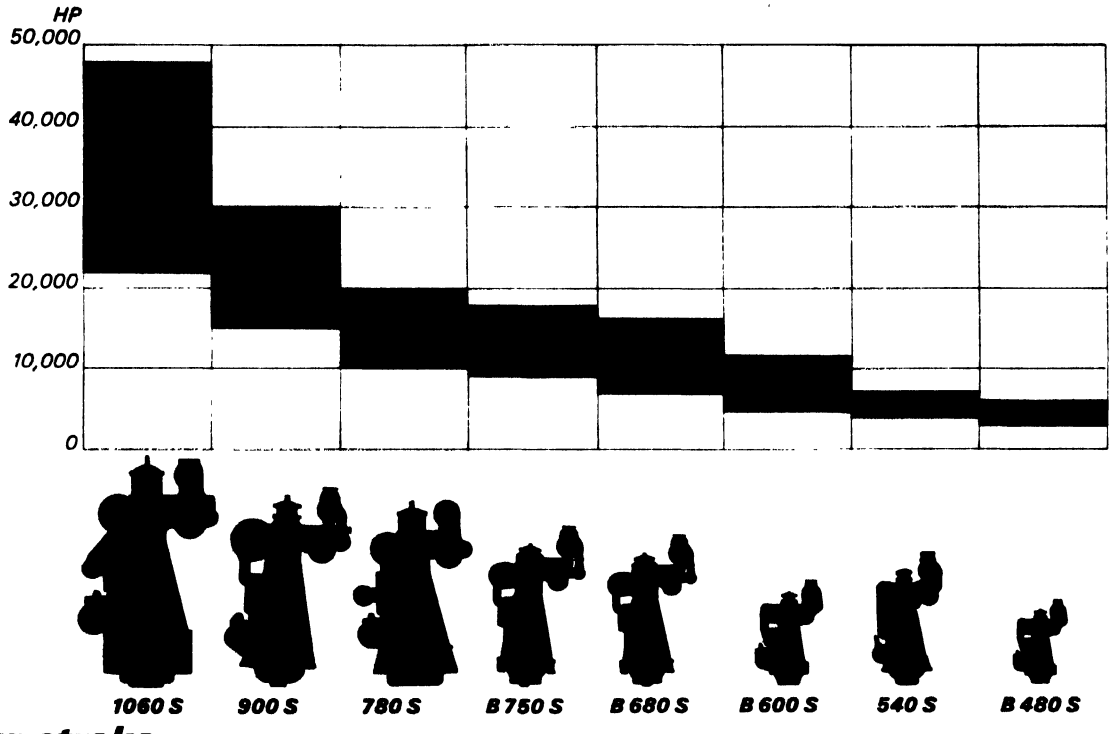
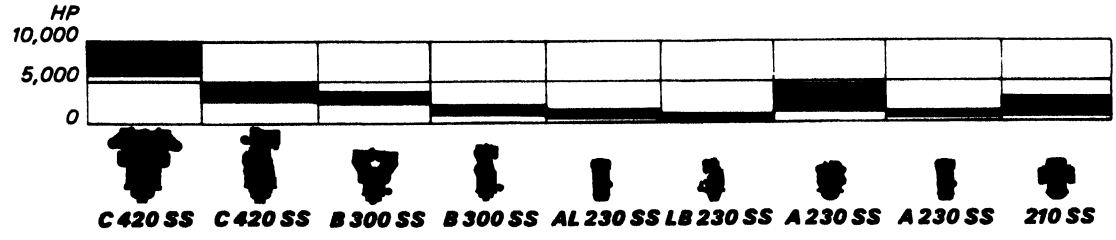


four-stroke



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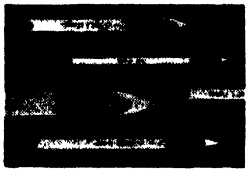

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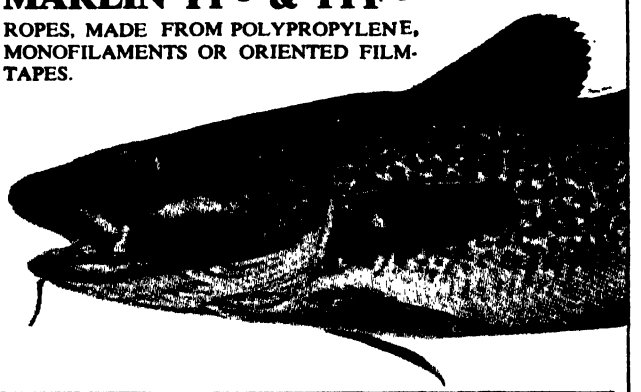

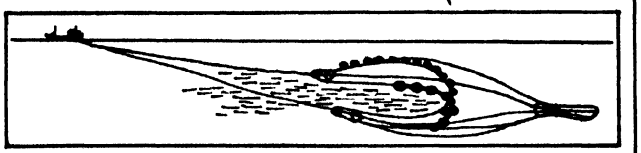

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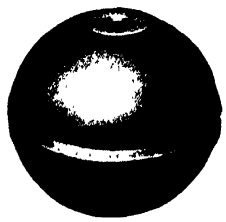

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FISH RESOURCES OF THE OCEAN

This book to be issued in 1972 represents years of work on the part of experts in FAO and elsewhere. The aim is to give as authoritative an estimate as possible of the actual commercial resources of the world's oceans. The individual statistical areas used in FAO's system of commercial catches is the basis used. Editor of the work is John Gulland (FAO), but working with him have been the leading experts in each area. Accompanying the work will be adaptations of the maps prepared for the special committee investigating the ocean bed resources, together with statistics and data. This work will be of high value to all fishery operators.

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(Publication 1972)

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1. **Development of the Stern Trawler by Gordon C. Eddie (White Fish Authority).**
2. **Trawling Gear and Equipment by Norman M. Kerr (White Fish Authority).**
3. **Handling the Catch by John J. Waterman (Torry Research, Aberdeen).**
4. **Small Stern Trawlers by John Burgess (Fishing News International).**
5. **Combination Stern Trawlers by Walter G. Scott (Canada).**

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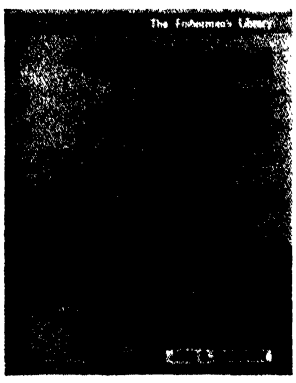

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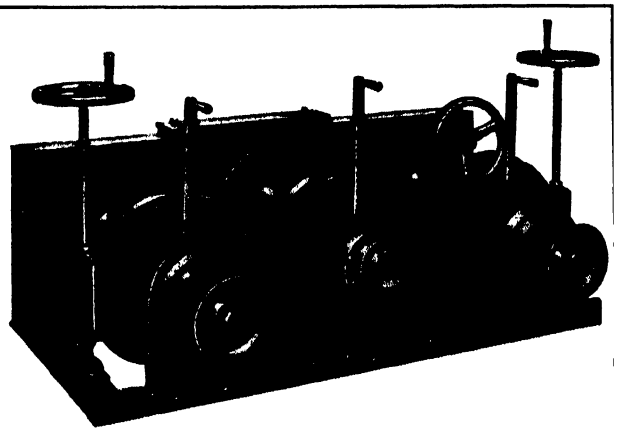

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